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THE ANDES OF ECUADOR–CHIMBORAZO FROM THE SOUTHEAST.

THE ANDES OF ECUADOR–THE CRATER OF QUILOTCA.

THE ANDES OF ECUADOR.

IN the western cordillera of the Andes, near Riobamba, stands the great Chimborazo, that mighty trachyte mountain—20,702 feet high—whose formation is still a subject of discussion, some maintaining that it is the result of masses thrown up by eruption and others that it is a volcano, the walls of which have been distended by the action of internal expanding gases.

Our picture shows the mountain from the southeast, having been taken from the Hacienda Zobol, across Troya. Although this giant has long since lost the reputation of being the highest mountain in the world, or even in the Andes, it still is and will continue to be the object of observation and admiration, because of important scientific investigations connected with it. Several attempts have been made to climb the mountain, but Strubel was the first to reach the summit, in 1872. La Condamine tried in vain in 1745, and Alexander von Humboldt could not go higher than 19,214 feet above the level of the sea.

The snow line is very irregular, but Strubel estimated that its average distance from the arched summit was from 4,900 feet to 5,200 feet, although some steep places on precipices, which are 19,000 feet high, are entirely free from snow, while in other places the ice on the top extends down as far as 15,400 feet. In June, July and August the least snow is usually found on Chimborazo, for during these months the cold east wind roars about the top of the mountain, preventing the formation and piling up of heavy masses of clouds such as usually deprive the mountain of the effects of the sun's rays. At this season the mountain is presented to view in its entire splendor for whole days, and the wind and sun work together to diminish the snow. Quickly passing snow storms are not lacking in these months, but they cover the bare stones for only a few hours, but give back its dazzling whiteness to the snow that had been colored red or a dirty gray by the dust blown on it. Our engraving shows the mountain when its covering of snow is least extensive; the line to which vegetation covers the stones protecting it from erosion is clearly indicated.

According to Strubel, the foot of the mountain at the south and east is a dreary waste. The paramo, which forms a characteristic feature of all mountainous regions, is to be found in its worst phase on Chimborazo. It is a region where the cultivation of the ground is either entirely prevented by the climatic conditions or the frequent frosts are a constant menace to the harvests. Strubel considers that the peculiarities of the paramo are caused by the severity and the sudden changes of the weather, which bring about conditions that are unfavorable for both man and beast.

From Strubel's rich collection of pictures of the Andes—which the owner intends to present to the museum in Leipzig when it goes into its new home—we have selected and publish herewith one representing the crater sea of Quilotoa. This is in the Western cordillera, near Latacunga, and our picture is taken from Hatalo, on the western edge of the crater, and 12,818 feet above the level of the sea. In the background we can see Cotopaxi, Iliniza and other giants of the Ecuador Andes. The view obtained here of Troya is so charming that it is easy to understand that its construction, as well as its coloring, must be most effective.—Illustrirte Zeitung.

THE BATTLE OF THE FORESTS.*

By Prof. B. E. FERNOW.

THE earth is a potential forest. Given time, freedom from geologic revolutions and from interference by man, the tree growth must finally dominate everywhere, with few excepted localities.

Its perennial nature and its elevation in height above all other forms of vegetation, together with its remarkable recuperative powers, assure to the arborescent flora this final victory over its competitors.

So impressed was Dr. Asa Gray with the persistence of individual tree life that he questioned whether a tree need ever die; "for the tree (unlike the animal) is gradually developed by the successive addition of new parts. It annually renews not only its buds and leaves, but its wood and its roots; everything, indeed, that is concerned in its life and growth. Thus, like the fabled Æson, being restored from the decrepitude of age to the bloom of early youth, the most recent branchlets being placed by means of the latest layer of wood in favorable communication with the newly-formed roots, and these extending at a corresponding rate into fresh soil, why has not the tree all the conditions of existence in the thousandth that is possessed of in the hundredth or the tenth year of its age?

"The old and central part of the trunk may, indeed, decay, but this is of little moment, so long as new layers are regularly formed at the circumference. The tree survives, and it is difficult to show that it is liable to death from old age in any proper sense of the term."

However this may be, we know trees succumb to external causes. Nevertheless, they are perennial enough to outlive aught else, "to be the oldest inhabitants of the globe, to be more ancient than any human monument, and exhibit in some of the survivors a living antiquity compared with which the mouldering relics of the earliest Egyptian civilization, the pyramids themselves, are but structures of yesterday." The dragon trees, so called, found on the island of Teneriffe, off the African coast, are believed to be many thousand years old. The largest is only 15 feet in diameter and 75 feet high. Our sequoias are more rapid growers, and attain in 3,000 to 4,000 years, which may be the highest age of living ones, more than double these dimensions.

While this persistence of life is one of the attributes which in the battle for life must count of immeasurable advantage, the other characteristic of arboreal development, its elevation in height above everything living, is no less an advantage over all competitors for light, the source of all life. Can there be any doubt that in this competition size must ultimately triumph and the undersized go to the wall?

Endowed with these weapons of defensive and offensive warfare, forest growth, through all geologic ages during which the earth supported life, has endeavored, and no doubt to a degree succeeded, in gaining possession of the earth's surface.

As terra firma increased, emerging in islands above the ocean, so increased the area of forest, changing in composition to correspond with the change of physical and climatic conditions.

As early as the Devonian age, when but a small part of our continent was formed, the mud flats and sand reefs, ever increasing by new accumulations under the action of the waves and currents of the ocean, were changed from a bare and lifeless world above tide level to one of forest-clad hill and dales.

Not only were such quaint forms as the tree rushes, Calamites, Lepidodendron and Sigillaria present, but the prototype of our pine, the Dadoxylon, had made its appearance.

The same class of flowerless plants known as vascular cryptogams, with the colossal tree ferns added, became more numerous and luxuriant in the Carboniferous age, as well as the flowering Sigillaria and coniferous Dadoxylon. This vegetation probably spread over all the dry land, but the thick deposits of vegetable remains accumulating in the marshy places under dense jungle growth and in shallow lakes with floating islands were finally, in the course of geologic revolutions, turned into the great coal fields.

In those and subsequent geologic times some of the floral types vanished altogether and new ones originated, so that at the end of Mesozoic times a considerable change in the landscape had taken place.

In addition to coniferous trees, the palms appeared, and also the first of angiosperms, such as the oak, dogwood, beech, poplar, willow, sassafras and tulip tree. Species increased in numbers, adapted to all sorts of conditions; the forest in a most varied and luxuriant form climbed the mountain sides to the very crests, and covered the land to the very poles with a flora of tropical and semi-tropical species.

Then came the leveling process and other changes of post-Tertiary or Quaternary times; the glaciation of lands in northern latitudes, with the consequent changes of climate, which brought about corresponding changes in the ranks of the forest, killing out many of the species around the north pole. Only the hardier races survived, and these were driven southward in a vertical route.

When these boreal times subsided in a degree, the advance of the forest was as sure as before, but the battle order was somewhat changed to suit the new conditions of soil and climate. Only the hardiest tribes could regain the northernmost posts, and these found their former places of occupancy changed by fluvial and lacustrine formations and the drifts borne and deposited by the ice sheets, while some by their constitution were entirely unfitted from engaging in a northern campaign, or found insurmountable barriers in the refrigerated east-west elevations of Europe and western Asia.

In addition, there had come new troubles from volcanic eruptions, which continually wrested the reconquered ground from the persistent advance guards of the arboreal army, annihilating them again and again.

Finally, when the more settled geologic and climatic conditions of the present era arrived, and the sun rose over a world ready for human habitation, man found what we are pleased to call the virgin forest—a product of long continued evolutionary changes—occupying most if not all the dry land, and ever intent upon extending its realm.

This prehistoric view of the battle of the forest cannot be left without giving some historic evidences of its truth.

Not only have palæobotanists unearthed the remnants of the circumpolar flora, which give evidence that it resembled that of present tropic and semi-tropic composition, but they have also shown that sequoias, magnolias, liquidambars and hickories existed in Europe and on our own continent in regions where they are now extinct. We have also evidences of the repeated successes and reverses of the forest in its attempts to establish itself through long geologic transformations.

One of the most interesting evidences of these vicissitudes in the battle of the forest is represented in a section of Amethyst Mountain in Yellowstone National Park, exhibiting the remains of fifteen forest growths, one above the other, buried in the lava. Again and again the forest subdued the inhospitable excoriations; again and again it had to yield to superior force.

Among these petrified witnesses of former forest glory, magnolia, oak, tulip tree, sassafras, linden and ash have been identified, accompanying the sequoia in regions where now only the hardiest conifer growths of pines and spruces find a congenial climate.

As the forest formed and spread thus during the course of ages, so does it form and spread to-day, unless man, driven by the increasing needs of existence, checks its progress and reduces its area by the cultivation of the soil. The natural extension of the forest cover or afforestation takes place readily whenever soil and climate is favorable, but it is accomplished just as surely, though infinitely slower, in unfavorable situations. On the naked rock, the coarse detritus and gravel beds, on the purely siliceous sand deposits of river and ocean, or in the hot, dry plains, the preliminary pioneer work of the lower vegetation is required. Algæ, lichens, mosses, grasses, herbs, and shrubs must precede to cultivate the naked rock, to mellow the rough moisture by shading the ground, and gradually render it fit for the abode of the forest monarch. The army of soil makers and soil breakers, the pioneers, as it were, of the forest, are a hardy race, making less demands for their support than those that follow. They come from different tribes, according to the soil conditions in which they have to battle.

The aspen (Populus tremuloides) is one of these forerunners, which is readily wafted by the winds over hundreds of miles, readily germinates and rapidly grows under exposure to full sunlight, and even now in the Rocky Mountains and elsewhere quickly takes possession of the areas which man has ruthlessly destroyed by fire. This humble and ubiquitous, but otherwise almost useless, tree is nature's restorative, covering the sores and scalds of the burnt mountain side, the balm poured upon grievous wounds. Though short-lived, with its light summer foliage turning into brilliant golden autumn hues, it gives grateful shade and preserves from the thirsty sun and wind some moisture, so that the better kinds may thrive and take its place when it has fulfilled its mission.

One of the shrubs or half trees which first take possession of the soil in the western mountain country is the so-called mountain mahogany (Cercocarpus ledifolius), covering the bared slopes after the fire has killed the old timber.

In other regions, as on the prairies of Iowa and Illinois, hazel bushes, or in the mountains of Pennsylvania and the Alleghanies in general, ericaceous shrubs like the laurel and rhododendrons or hawthorn, viburnum and wild cherry are the first comers, while along watercourses alders and willows crowd even the water into narrower channels, catching the soil which is washed from the hillsides and increasing the land area.

One of the most interesting soil makers, wresting new territory from the ocean itself, is the mangrove along the coast of Florida. Not only does it reach out with its aerial roots, entangling in their meshes whatever litter may float about, and thus gradually building up the shore, but it pitches even its young brood into the advance of the battle, to wrestle with the waves, and gain a foothold as best it may.

Not less interesting in this respect is that denizen of the southern swamp, the bald cypress, with its curious root excrescences known as cypress knees, which, whatever their physiologic significance, are most helpful in expediting changes of water into land sufficiently dry to be capable of supporting the more fastidious species in regard to moisture and conditions.

On the dry hot mesas, and in the arroyos of the southwestern tier of our States and Territories, we meet a different set of skirmishers following up the huge cacti and agaves, which, together with the tree yuccas, penetrate into the very desert. In these regions the mesquite or algaroba and others of the acacia tribe form the second phalanx, as it were, gradually advancing their lines in spite of adverse conditions. In other regions the pine, satisfied with but scanty favor of soil moisture, and the spruce, able to sustain life in shallow soil, and the fir, in the higher, colder, and wetter elevations, sometimes much stunted, form the skirmish line. These improve the soil in its moisture conditions by their shade, and by the foliage and litter falling and decaying they deepen the soil, forming a humus cover. The duff that is found covering the rocky subsoil of the Adirondacks is formed in this way at the rate of about 1 foot in 500 years. They are soon followed by the birch, maple, elm, and ash, and in moister situations by the oak—first, that hardy pioneer, the black oak tribe, and then the more fastidious white oak, with whom the slower but persistent hickories, beeches, and other shade-enduring species begin to quarrel for the right of occupancy of the ground, until the battle is no longer that of the forest against the elements and lower vegetation, but between the mighty conquerors themselves. This struggle we can see going on in our primeval forests, wind, storms, and decay acting as allies now to one, now to the other side, and thus changing the balance of power again and again.

In this struggle for supremacy between the different arborescent species the competition is less for the soil than for the light, especially for tree growth. It is under the influence of light that foliage develops, and that leaves exercise their functions and feed the tree by assimilating the carbon of the air and transpiring the water from the soil. The more foliage and the more light a tree has at its disposal, the more vigorously it will grow and spread itself.

Now the spreading oak or beech of the open field finds close neighbors in the forest, and is narrowed in from all sides and forced to lengthen its shaft, to elevate its crown, to reach up for light, if it would escape being overshadowed, repressed, and perhaps finally killed by more powerful densely-foliaged competitors.

The various species are differently endowed as regards the amount of light which they need for their existence. Go into the dense forest and see what kinds of trees are vegetating in the dense shade of the older trees, and then go into the opening recently made, an abandoned field or other place, where the full benefit of light is to be had by all alike, and one will find a different set altogether occupying the ground and dominating. In the first case there may be found, perhaps, beech and sugar maple or fir and spruce; in the second case aspen, poplar, willow, soft maple, oak or pine, tamarack, etc.

All trees thrive ultimately best in full enjoyment of light. But some, like those first mentioned, can at least subsist and their foliage functionate with a small amount—they are shade enduring kinds, usually having a dense foliage, many leaves, and each one needs to do but little work—and exert considerable shade when fully developed. Those last named, however, are light-needing kinds, and having less foliage, cannot exist long without a considerable amount of light.

To offset this drawback in the constitution of these latter, nature has endowed them as a rule with the capacity of rapid height growth, to escape their would-be suppressors; but again, what they have gained in the rapidity of development they lose in the length of life. They are mostly short-lived species, while the shade-enduring are generally slower growers, but persistent and long-lived. Some kinds, like most of the oaks, stand between the two; while exhibiting a remarkable capacity of vegetation in the shade, they are really light-needing species, but comparatively slow growers and long-lived. One of the same species behaves also somewhat differently under different soil and climatic conditions; for instance, as a rule, the light-needing species can endure more shade on moist soils, and the shade-enduring require more light on drier soils.

In the earliest stages of life the little seedlings of most trees require partial shade, and are quite sensitive in regard to light and conditions. Some have such a small range of light and shade endurance that, while there may be millions of little seedlings sprouted, they will all perish if some of the mother trees are not removed and more light given; and they will perish equally if the old growth is removed too suddenly, and the delicate leaf structure, under the influence of direct sunlight, is made to exercise its functions beyond its capacity.

* A lecture delivered by Prof. B. E. Fernow, Chief of the Forestry Division, Department of Agriculture, U. S. A., during the Brooklyn meeting of the American Association for the Advancement of Science, 1894.

Left to itself the forest grows up, and as the individual trees develop, each trying to hold its ground and struggling for light, a natural thinning takes place, some trees lagging behind in growth and being shaded out, until in old age only as many trees remain as can occupy the ground without incommoding each other.

This struggle among the individuals goes on during their entire life. Some few shoot ahead, perhaps, because of a stronger constitution or some favorable external cause, and overtower their neighbors. These, lagging behind, fall more and more under the shading influence of their stronger neighbors until entirely suppressed, when they only vegetate until they die. The struggle continues, however, among the dominant class, and it never ends.

Thus the alternations of forest growth take place, oak following pine, or pine following oak; the poplar, birch and cherry appearing on the sunny burns, or the hickory, beech and maple creeping into the shadier pine growths. While in the eastern forests under natural conditions the rotation of power is accomplished in at least from 300 to 500 years, the old monarchs of the Pacific, towering above all competitors, have held sway 2,000 or more years. In this warfare, with changes in climatic and soil conditions going on at the same time, it may well occur that a whole race may even be exterminated.

The study of the formative period of the forest is necessary in order to show clearly that the virgin forest is a product of long struggles, extending over centuries, nay, thousands of years. Some of the mightiest representatives of the old families, which at one time of prehistoric date were powerful, still survive, but are gradually succumbing to their fate in our era.

The largest of our eastern forest trees, reaching a height of 140 feet and diameters up to twelve feet, the most beautiful and one of the most useful, the tulip tree (Liriodendron tulipifera), is a survivor of an early era, once widely distributed, but now confined to eastern North America, and doomed to vanish soon from our woods through man's improper partisanship.

Others, like the Torreya and Cupressus, seem to have succumbed to a natural decadence, if we may judge from their confined limits of distribution. So, too, the colossal sequoias, remnants of an age when things generally were of a larger size than now, appear to be near the end of their reign, while the mighty taxodium or bald cypress, the big tree of the East, still seems vigorous and prosperous, being able to live with wet feet without harm to its constitution, weird with the gray tillandsia or Spanish moss.

Having thus scanned through the traditions of unwritten history of the battle of the forest, having seen some of the combatants in the struggle and learned something of their methods of conquering the earth and each other, we may take a look at the condition of things on the North American continent as it presumably was in the beginning of historic times or within our century.

As far as occupancy of the soil by the forest is concerned, we find that the struggle had not yet been determined in its favor everywhere. While a vast territory on the Atlantic side and a narrower belt on the Pacific coast, connected by a broad belt through the northern latitudes, was almost entirely under its undisputed sway, and while the backbone of the continent, the crest and slopes of the Rocky Mountains, was more or less in its possession, there still remained a vast empire in the interior unconquered.

Of parts of this territory we feel reasonably certain from strong evidences that the forest, once occupied them, but has been driven off by aboriginal man, the firebrand taking sides with the grasses, and the buffalo probably being a potent element in preventing re-establishment. In other parts it is questionable whether the lines along the river courses, the straggling trees on the plateaus and slopes, are remnants of a vanquished army or outposts of an advancing one. In some parts, like the dry mesas, plateaus and arroyos of the interior basin and the desert-like valleys toward the southern frontiers, it may reasonably be doubted whether arborescent flora has more than begun its slow advance from the outskirts of the established territory.

Certain it is that climatic conditions in these forestless regions are most unfavorable to tree growth, and it may well be questioned whether in some parts the odds are not entirely against the progress of the forest.

Temperature and moisture conditions of air and soil determine ultimately the character of vegetation, and these are dependent not only on latitude, but largely on configuration of the land, and especially on the direction of moisture-bearing winds with reference to the trend of mountains.

The winds from the Pacific Ocean striking against the coast range are forced by the expansion and consequent cooling to give up much of their moisture on the windward side; a second impact and further condensation of the moisture takes place on the Cascade range and Sierra Nevada. On descending, with consequent compression, the wind becomes warmer and drier, so that the interior basin, without additional sources of moisture and no additional cause for condensation, is left without much rainfall and with a very low relative humidity—namely, below 50 per cent. The Rocky Mountains finally squeeze out whatever moisture remains in the air currents, which arrive proportionally drier on the eastern slope. This dry condition extends over the plains until the moist currents from the Gulf of Mexico modify it. Somewhat corresponding, yet not quite, to this distribution of moisture, the western slopes are found to be better wooded than the eastern, and the greater difficulty of establishing a forest cover here must be admitted; yet since the forest has the capacity of creating its own conditions of existence by increasing the most important factor of its life, the relative humidity, the extension of the same may only be a question of time.

Temperature extremes, to be sure, also set a limit to tree growth, and hence the so-called timber line of high mountains, which changes in altitude according to the latitude.

If now we turn our attention from the phyto-topographic consideration of the forest cover to the phytogeographic and botanical features, we may claim that the North American forest, with 425 or more arborescent species, belonging to 158 genera, many of which are truly endemic, surpasses in variety of useful species and magnificent development any other forest of the temperate zone, Japan hardly excepted. In addition, there are probably nowhere to be seen such extensive fields of distribution of single species.

These two facts are probably explained by the north and south direction of the mountain ranges, which permitted a re-establishment after the ice age of many species farther northward, while in Europe and the main part of Asia the east-west direction of the mountains offered an effectual barrier to such re-establishment, and reduced the number of species and their field of distribution; nor are the climatic differences of different latitudes in North America as great as in Europe, which again predicates greater extent in the fields of distribution north and south. On the other hand, the differences east and west in floral composition of the American forest are greater than if an ocean had separated the two parts instead of the prairie and plains. This fact would militate against our theory that the intermediate forestless region was or would be eventually forested with species from both the established forest regions, if we did not find some species represented in both regions and a junction of the two floras in the very region of the forestless areas.

In the sand hills which traverse Nebraska from east to west there are now found in eastern counties the sand-drowned trunks of the western bull pine, and the same pine belonging to the Pacific flora is found associated with the black walnut of the eastern region along the Niobrara River.

We may, however, divide the North American forest, according to its botanical features, into two great forest regions—namely, the Atlantic, which is in the main characterized by broad-leaved trees, and the Pacific, which is made up almost wholly of coniferous species. In the Atlantic forest we can again discern several floral subdivisions, each of which shows special characteristics. The southernmost coast and keys of Florida, although several degrees north of the geographical limit of the tropics, present a truly tropical forest, rich in species of the West Indian flora, which here finds its most northern extension. There is no good reason for calling this outpost semi-tropical, as is done on Sargent's map. With the mahogany, the mastic, the royal palm, the mangrove, the sea grape and some sixty more West Indian species represented, it is tropical in all but its geographic position. That the northern flora joins the tropic forest here and thus brings together on this insignificant spot some hundred species, nearly one-quarter of all the species found in the Atlantic forest, does not detract from its tropical character.

On the other hand, the forest north of this region may be called sub-tropical, for here the live and water oak, the magnolia, the bay tree and holly, and many other broad-leaved trees are mixed with the sabal and dwarf palmetto. As they retain their green foliage throughout the winter, this region is truly semi-tropical in character, and, under the influence of the Gulf Stream, extends in a narrow belt some twenty or twenty-five miles in width along the coast as far north as North Carolina.

While this ever-green, broad-leaved forest is more or less confined to the rich hammocks and moister situations, the poor sandy soils of this, as well as of the more northern region, are occupied by pines; and as those, especially the long-leaf pine, are celebrated all over the world and give the great mercantile significance to these forests, this region may well be called the great southern pine belt. North of the evergreen subtropic forest stretches the vast deciduous leaved forest of the Atlantic, nowhere equaled in the temperate regions of the world in extent and perfection of form and hardly in the number of species. This designation applies to the entire area up to the northern forest belt, for the region segregated on the census map as the northern pine belt is still, in the main, the dominion of the deciduous leaved forest trees. On certain areas pines and spruces are intermixed, and on certain soils, especially gravelly drifts and dry sand plains, as on the pine barrens of Northern Michigan, they congregate even to the exclusion of other species.

Instead, we can divide this deciduous leaved forest by a line running somewhere below the fortieth degree of latitude, where, with the northern limits of the southern magnolias and other species, we may locate in general the northern limit of the southern forest flora.

Northward from here, in what may be called the "middle Atlantic forest," the deciduous species rapidly decrease, and the coniferous growth predominates until we arrive at the broad belt of the northern forest, which, crossing from the Atlantic to the Pacific, and composed of only eight hardy species, takes its stand against the frigid breath and icy hands of Boreas.

Abounding in streams, lakes and swampy areas, the low divides of this region are occupied by an open stunted forest of black and white spruce, while the bottoms are held by the balsam fir, larch or tamarack, poplar, dwarf birch and willow. The white spruce, paper or canoe birch, balsam poplar and aspen stretch their lines from the Atlantic to the Pacific over the whole continent.

On the Pacific side the subdivisions are rather ranked from west to east. While the northern forest battles against the cold blasts from icy fields, the front of the Pacific interior forest is wrestling with the dry atmosphere of the plains and interior basin. Here, on the driest parts, where the sage brush finds its home, the ponderous bull pine is the foremost fighter, and where even this hardy tree cannot succeed in the interior basin several species of cedar hold the fort in company with the nut pine, covering with an open growth the mesas and lower mountain slopes. Small and stunted, although of immense age, these valiant outposts show the marks of severe struggles for existence.

On the higher, and therefore moister and cooler elevations, and in the narrow canyons, where evaporation is diminished and the soil is fresher, the somber Douglas, Engelmann and blue spruce, and the silver-foliaged white fir join the pines or take their place.

With few exceptions, the same species, only of better development, are found in the second parallel, which occupies the western slopes of the Sierra Nevada. Additional forces here strengthen the ranks, the great sugar pine, two noble firs, a mighty larch, hemlocks and cedars vie with their leaders, the big sequoias, in showing of what metal they are made. The third parallel, occupied by the forest of the coast range, the most wonderfully developed, although far from being the most varied of this continent, is commanded by the redwood, with the tide-land spruce, hemlock and gigantic arborvitæ joining the ranks.

Broad-leaved trees are not absent, but so little developed in comparison with the mighty conifers that they play no conspicuous part except along the river bottoms, where the maple, cottonwood, ash and alder thrive, and in the narrow interior valleys, where an open growth of oak is found. Toward the south and on the lower levels these broad-leaved trees again become evergreen, as on the Atlantic side, but of different tribes, and form a sub-tropic flora.

Along the coast we find several species of true cypress, including the well-known, although rare, Monterey cypress, which clings to the gigantic rocks and braves the briny ocean winds, and with its branches twisted landward. Finally, flanking the battle order of the Pacific forest, we find another section of the army, composed of the northern extension of the Mexican flora, mingled with which are species from the Pacific forest on the west, and from the Atlantic on the east.

The mesquite and some acacias, the tree yuccas and the giant or tree cactus are perhaps the most characteristic and remarkable species of the deserts of this region, while the high mountains support dense forests of firs and pines.

So far we have considered the forest only from the geographical and botanical point of view, and have watched the history of its struggle for existence against the elements and against the lower vegetation and other forces of nature. A new chapter of its life history, which we shall have time only to scan very briefly, began when man came upon the scene, and the economic point of view had to be considered.

For ages man has taken sides against the forest. Not only has he contested for the occupancy of the soil in order to cultivate his crops or to make the meadow for his cattle—a most legitimate and justifiable proceeding—and not only has he utilized the vast stores of wood accumulated through centuries for the ten thousand uses to which this material can be applied, and in the application of which he exhibits his superior intelligence, but he has also shown a woful lack of intelligence in the willful or careless destruction of the forest without justifiable cause, and by just so much curtailing the bountiful stores provided by nature for him and his progeny. Not only has he, like a spendthrift, wasted his stores of useful material, but more—he has wasted the work of nature through thousands of years by the foolish destruction of the forest cover, wresting from it the toilsomely achieved victory over the soil. He has destroyed the grasses and even all vestige of vegetation, and has handed over the naked soil to the action of wind and water. As the fertility and agriculture of the plain is dependent upon the regular and equable flow of water from the mountains, such as a forest cover alone can secure, he has by baring the slopes accomplished in many localities utter ruin to himself and turned them back into inhospitable deserts as they were first before the struggle of the forest had made them inhabitable.

One would hardly believe that certain mountains in France had ever seen a luxuriant forest growth and could during historic times have been so utterly despoiled of their vegetal cover. Yet ax, fire and cattle have been most successful, and the consequences have been felt not only in the mountains, but in the valleys below.

The waters in torrents have brought down the soil and debris, covering out of sight the fertile fields of thousands of toiling farmers. They themselves have brought this ruin upon them on account of their ignorance of the relation of forest cover to their occupation. Now, with infinite hard work and expenditure of energy and money, the slow work of restoring the forest to its possession has begun. The first work is to take care of the rain waters, and by artificial breaks turn them from rushing torrents over the bare surface into a succession of gentle runs and falls by fascine and stone works. This work must be begun at the very top of the mountains, at the very source of the evil, where the water receives its first momentum in the descent to the valley. The fascines or watties, laid across each rivulet at more or less frequent distances from each other and fastened down by heavy stones, are made of live willows or other readily sprouting species, which in course of time strike root and become living barriers. The pockets behind these breastworks gradually fill up, and the contour of the mountainside is changed from an even and rapid descent into a series of steps with gentle fall, over which the formerly rushing waters, gradually and without turbulence, find their way to the valley below.

Where the incline is too steep and higher breastworks are necessary, they are made of masonry, sometimes at great expense. At the base of these overflow dams an opening is left for the water to drain through, even after the depression behind the rampart has filled up with debris and soil has washed down from above. Then, when in this way the soil has come to rest, forest planting begins, and gradually the torrent is "drowned in vegetation." Sometimes, where on a steep mountainside the naked rock alone has been left, it becomes necessary to carry in baskets the soil to the trenches hewn in the rock, where the little seedlings may take their first hold until they are strong enough to fight their own battle and make their own soil, gradually restoring the beneficent conditions which nature had provided before the arrival of man and his senseless, improvident, self-destructive greed. By the irrational destruction of the forest, first for the supply of timber, then through the careless use of fire, by the clearing for unsuitable farm use, by excessive grazing of sheep and goat, the mountainsides themselves are not only devastated and made useless, but fertile farms for two hundred miles from the source of the evil are ruined by the deposits of debris, and the population pauperized and driven from their homes.

Many millions of dollars have been and many more will have to be spent before these regions become habitable again.

That we are working in this country toward the same

conditions is too well known to need rehearsal. Go to the shores of Lake Michigan, or visit the coast of New England, New Jersey, Pennsylvania, down to the Gulf, and you can see the destructive action of the shifting sands set loose by improvident removal of the plant cover. Go to the Adirondacks, the highlands of the Mississippi, or the eastern slopes of the Rocky Mountains, and aspects similar to those derived from France will meet your view.

What the farmer has brought upon himself here by excessive clearing, the lumberer, prospector, miner or hunter prepares in the farthest West by reckless and purposeless use of fire. Burned, mountainsides, where no living thing can subsist in comfort, cover not acres but hundreds of square miles in the western country. While the first fire only deadens the trees or undermines their constitution, the second or third fire usually is sufficient to kill what remain alive, and even to clean up the fallen timber. That these bald spots are not more frequent than they are is only due to the short period of our endeavors in disturbing the balance of nature.

But as our nation prides itself on the rapidity of its development, exercising to the utmost our constructive energies, so do we excel in destructive and wasteful energies and tendencies, and we shall come to grief with our resources much sooner than some of our happy-go-lucky friends would like to make us believe. While these exhibitions of American vandalism are beyond the proprieties of legitimate warfare, there is not much more propriety or intelligence visible in the manner in which we levy tribute from the forest for our legitimate needs. Forests grow to be used, but there is a great difference between intelligent and unintelligent use. Improvidence and ignorance characterize the present methods of using the forest growth. The value of it is not even known. Of the 425 or more species which are represented in the forests, not more than forty or fifty at the most are found in the markets. Although, to be sure, many of the species are of but little or no economic value, the number of the truly useful trees is probably twice or three times as great as that actually used. Ignorance as to the true value of them keeps many from little more than simply a strictly local use, or from their most fit employment.

The story of the black walnut used for fence rails or firewood is well known. Six years ago the red gum or liquidambar, now a fashionable finishing material, was despised. Ten years ago large hemlock trees were mouldering in the woods after the bark had been taken for tanning purposes, because the value of the wood was unknown. Cypress and Douglas spruce cannot yet overcome the prejudice of the market. On the other hand, cottonwood and tulip poplar, not long ago among the despised or only locally used, can hardly now be furnished in sufficient quantities, and the long leaf pine, which had been bled for turpentine, was considered an inferior material, which, as has lately been shown, is nothing but an unwarranted prejudice.

In a vague, empirical way the choice of the useful has been attempted, and only lately have we begun to systematically study our forest resources, to determine the qualities and adaptabilities of our timbers, and to find out the conditions under which they produce not only the largest amount, but the best quality of timber.

Yet in another direction do the forest users act unintelligently. As we have seen, most of our forest trees are of a social character. With few exceptions, they keep company with other kinds than their own; they appear in mixed forests. Hence, where certain species, as the pines and spruces, become gregarious and form unmixed pure forests, the ax of the lumberer does not, as a rule, level the entire forest, but he selects the kinds which he wishes to use—he culls the forest. At first sight this would appear rather an advantage for the existence of the forest. So it is from a botanic, geographic or landscape point of view, yet from an economic point it is exactly the reverse—it is disastrous.

In the well managed forests of Germany the undeserving species are exterminated, and the most useful fostered, just as the agriculturist exterminates the weeds and cultivates the crop. Not only is the forest there confined to those soils and locations which cannot be used to better advantage, or which require a forest cover in order to protect the soil against detrimental displacement, but it is so managed as to become a more and more valuable resource, a crop of increasing importance, under the management of skilled foresters, of whom, in a late debate on the floor of the Landtag of Prussia, it was said that "While most other productive business has declined, the forest administration has steadily improved and yielded increasing revenues."

The battle of the forest in this country is now fought by man, the unintelligent and greedy carrying on a war of extermination, without the knowledge that victory may lead eventually to their own destitution; the intelligent and provident trying to defend the forest cover, and endeavoring to prevent its removal from such lands as cannot serve a better purpose, and to restrict the use of the balance to such rational harvest of its material, without injurious effects on soil and water conditions, as will insure an ever-reproducing crop and a permanent national resource.

While man may study the geography of the earth as it exists, here is about the only opportunity for him to make geography, to shape the surface conditions of the earth, and even to some extent influence its climatic conditions.

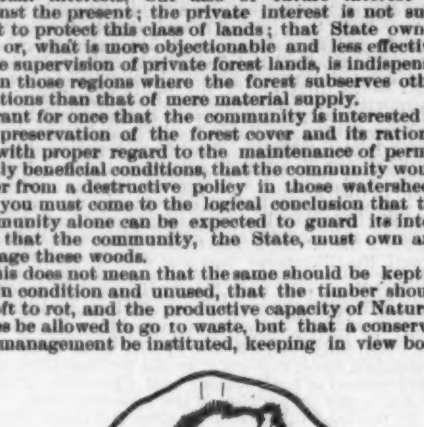
The lecturer then referred to the Adirondacks in particular, showing views of forest destruction by fire, water storage and lumbering, and claiming that they need especially conservative treatment, because the soil itself there is made by the forest, the duff covering the native rock formed at the rate of one foot in 300 to 500 years by the decay of foliage and litter, and hence its loss by washing of the rains is practically irremediable.

He showed the paramount interest which the State has in maintaining favorable forest conditions, and claimed that the private owners, being naturally interested mostly in the timber only, and not caring for the future generations or distant and indirect benefits to others, could not be expected to manage conservatively.

Let it not be overlooked, that the State is not only the representative of communal interests as against individual interests, but also of future interest as against the present; the private interest is not sufficient to protect this class of lands; that State ownership or, what is more objectionable and less effective, State supervision of private forest lands, is indispensable in those regions where the forest subserves other functions than that of mere material supply.

Grant for once that the community is interested in the preservation of the forest cover and its rational use with proper regard to the maintenance of permanently beneficial conditions, that the community would suffer from a destructive policy in those watersheds, and you must come to the logical conclusion that the community alone can be expected to guard its interests, that the community, the State, must own and manage these woods.

This does not mean that the same should be kept in virgin condition and unused, that the timber should be left to rot, and the productive capacity of Nature's forces be allowed to go to waste, but that a conservative management be instituted, keeping in view both



the indirect and the direct benefits of the forest cover, utilizing the crop without detriment to the forest conditions.

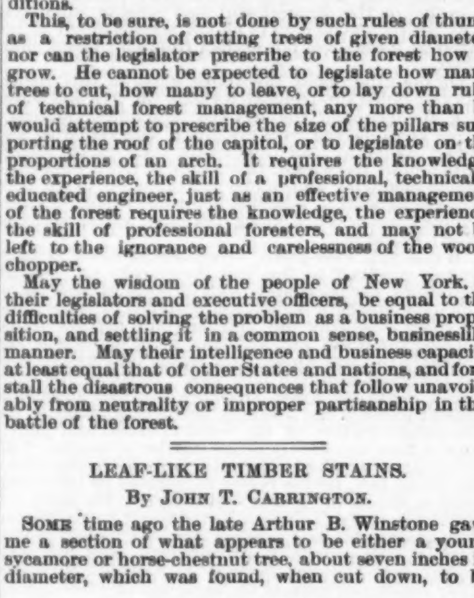
This, to be sure, is not done by such rules of thumb as a restriction of cutting trees of given diameter, nor can the legislator prescribe to the forest how to grow. He cannot be expected to legislate how many trees to cut, how many to leave, or to lay down rules of technical forest management, any more than he would attempt to prescribe the size of the pillars supporting the roof of the capitol, or to legislate on the proportions of an arch. It requires the knowledge, the experience, the skill of a professional, technically educated engineer, just as an effective management of the forest requires the knowledge, the experience, the skill of professional foresters, and may not be left to the ignorance and carelessness of the woodchopper.

May the wisdom of the people of New York, of their legislators and executive officers, be equal to the difficulties of solving the problem as a business proposition, and settling it in a common sense, businesslike manner. May their intelligence and business capacity at least equal that of other States and nations, and forestall the disastrous consequences that follow unavoidably from neutrality or improper partisanship in this battle of the forest.

LEAF-LIKE TIMBER STAINS.

By JOHN T. CARRINGTON.

SOME time ago the late Arthur B. Winstone gave me a section of what appears to be either a young sycamore or horse-chestnut tree, about seven inches in diameter, which was found, when cut down, to be



curiously stained in a leaf-like pattern, as depicted in the upper figure on this page. The wood is perfectly solid and healthy looking, and the odd part of the stain is, that it apparently ran the whole length of the tree with equal intensity, much after the manner of the "oak tree" seen in the stem of our common bracken when a section is cut through. Mr. Winstone told me that the tree was grown near Cambridge, and some slices about two inches thick had been obtained by Mr. Clay of that town, who had given him specimens and such particulars as he possessed about them.

Beyond valuing this piece of timber as a remarkable coincidence between the stain and the shape of a sycamore leaf, I thought little more about the specimen until last winter Mr. Goldney Willis, of Indianford, Manitoba, then residing at Leatherhead in Surrey, brought me, without knowing anything about the Cambridge example, a similar section of wood, about an inch larger in diameter, taken from a plane tree which had died and then been cut down in his father's garden at Leatherhead. Just as in the Cambridge tree, the stain, which is drawn in the lower figure, ran the whole length of the trunk. In this case the center of the wood within the stain is decayed, apparently through the action of a fungoid growth.

Although one must reluctantly think that these stain shapes are only accidental and have nothing whatever to do with the shape of the leaves of the tree in the stem of which they occurred, the coincidence seems most remarkable. Last summer I showed the specimens to Mr. Carruthers, F.R.S., the head of the botanical department of the British Museum, who, though he had never before seen a like case of stain in nature, agreed with me that it was only accidental in each tree. Blurs and smudges of color are not infrequent in sections of timber, specimens being on view in the botanical galleries at South Kensington, but definite patterns are rare.—Science-Gossip.

SPRAYING FOR BLACK KNOT UPON CHERRIES AND PLUMS.

IN the spring of 1893 some experiments were begun at the Cornell Station to determine the value of the Bordeaux mixture in controlling the black knot of plums and cherries. This disease has proved fatal to so many trees, and even entire orchards, that it is a continual menace to the growers of these fruits. It probably has caused greater losses in New York than the dreaded peach yellows, and during some seasons it has spread with such rapidity that all efforts for its control were practically useless. The disease has consequently had its own way in the large majority of cases.

All scientists now agree in ascribing the cause of black knot to a fungus; but, although the parasite has long been known, its life history has not yet been completely worked out. It is known, however, that the fungus produces large numbers of spores, and these are supposed to obtain an entrance into the host plant some time during the warmer months. Just how or when this takes place still remains to be shown. Humphrey says* that the knots first appear in the fall as "slight swellings of the branch." I have failed to find any distinct indication of the knots before early spring; yet there appears to be little doubt of the fact that most, if not all, of the newly infested parts fail to show the presence of the fungus by the formation of new knots until the following spring or early summer. In other words, it now seems probable that infection takes place during one season, but well developed knots do not appear until the following year.

Several experiments were planned with the above theory as a basis. The fungicide used was the Bordeaux mixture, as this has come to be recognized as our most efficient compound for the prevention of fungous diseases. The trees selected for the work were plums and cherries, but only one case, that of some cherry trees, will be here mentioned. The trees were mostly sprouts which had been allowed to grow to a height of eight to ten feet. They sprang from the roots of some Morello trees which were set many years ago, and at the time of the beginning of the treatments the old trees and the younger ones were thoroughly entangled, and they were also well covered with knots. The thicket, for so it might be called, was divided into two nearly equal parts by cutting out the brush on a line passing nearly through the center. One part was sprayed, but the other remained untreated. No knots were cut out during the first year.

The first application was made March 29, 1893, and this was followed by others upon the following days: April 18, May 6 and 30, and June 13. Notes taken June 13 show that new knots were forming as abundantly upon the treated as upon the untreated half. No further treatment were made during this year.

The first application in 1894 was made April 9. This was repeated on the 25th of the same month, and at this time all the knots were removed from the entire ticket. They appeared to be equally abundant upon each plot, and for greater accuracy in drawing conclusions, the number cut from each side was counted. Additional applications were made May 22, June 6 and 27, July 10 and 20, and August 1.

On November 26 all the knots were again cut out and counted. A comparison of the numbers of knots cut in the spring of 1894 and of those cut in the fall should indicate to a greater or less degree the value of the treatments. But whether the treatments of 1894 are wholly or only partially instrumental in bringing about the final result cannot now be stated with certainty. The results were these:

In the spring of 1894 the number of knots cut from the unsprayed trees was 2,002 and from the sprayed trees 1,155.

In the autumn of 1894 the number of knots cut from the unsprayed trees was 3,466 and from the sprayed trees 165.

These figures show an enormous gain in favor of the sprayed portion. And this gain is emphasized still more if it is assumed, as may justly be done, that the same ratio of increase in the number of knots shown in the unsprayed plot would also have taken place in the sprayed portion, provided no treatments had been made. In this case the 165 knots cut in the fall must be compared, not with the 1,155 knots cut in the spring, but with 2,000, since this is within a fraction of the number assumed to have been produced, had no application been made.

It cannot be held that absolute protection has been effected by the treatments, but it is not very often that such a statement can be made, even with plant diseases, which are now regularly treated by the use of fungicides. One must also take into consideration that the sprayed trees were standing so near to the other portion of the row that the branches of the two lots almost touched each other. In addition to this the knots had been allowed to remain on the trees until all the winter spores had been disseminated and the spread of the disease had been favored as much as possible. If we knew more regarding the time and manner of infection, we should know better when and

* Eighth Annual Report Massachusetts State Agricultural Station, p. 205.

how to apply the treatment so that it would be most effective. If the results of further experimentation agree with the case mentioned above, we may soon have a definite direction for the treatment of this fungus, as we now possess in the case of other plant diseases over which we once had no control, but for which we now have practical and efficient remedies.

Cornell University. E. G. LODEMAN.

THE GLOWWORM.

By E. A. BUTLER, B.A., B.Sc.

THE townsman seldom has the opportunity, often enjoyed by those who live in country districts, especially in the southern parts of England, of seeing what cannot fail to be regarded as one of the most remarkable sights in nature—a living animal glowing with light as if it were on fire. The production of light is so frequently a consequence of the phenomenon of combustion, that it is difficult to dissociate them in the mind, and to imagine the former without being impelled to think of the latter, or at least to imagine a considerably elevated temperature. The production of brilliant light without any sensible increase of heat is so unusual a circumstance that it is puzzling to understand how it can take place, and still more, how it can be associated with a living animal frame. The glowworm is by far the most important terrestrial animal in Great Britain that manifests this phenomenon of "phosphorescence," though among marine animals, and among terrestrial species belonging to warmer latitudes, the phenomenon is of very much wider occurrence. In fact, there are few classes of animals that do not contain species which are, at some season or other, more or less phosphorescent; fishes, insects, myriapods, crustacea, mollusca, sea squirts, worms, cœlenterates, starfishes, infusoria, all include phosphorescent species. In fact, so common is the phenomenon among marine organisms, that apparently we have in it the chief source of light to those creatures that live in the abysmal depths of the ocean, where the sun never penetrates. But while the sea teems with glowing animals, they are not nearly so numerous on land, and, as already mentioned, the glowworm is, in this country, practically the only terrestrial phosphorescent species which is likely to attract general attention, the few centipedes, worms, etc., that are its only rivals, being far inferior to it in brilliancy.

But it is not only as a phosphorescent being that the glowworm is remarkable. In a great variety of respects it is abnormal, and these peculiarities we will now proceed to recount. It may be a surprise to some of our readers to be told that the glowworm is a beetle, i. e., a member of the order Coleoptera, to which also belong the blister beetle, the bloody-nose beetle, the bombardier beetle, and others that we have recently described. It is most nearly related to that section of the order which includes the well-known "soldiers and sailors," the reddish and bluish-black, soft-bodied flying insects that are so common in summer, not only in the woods and fields, but in the streets of our towns as well. Usually it is not reckoned as belonging to the same family as these creatures, but is placed in a different one next to them. This family is called Lampyridæ, and the English glowworm is known as Lampyris noctiluca. It is the only species of its genus with which we are favored in Great Britain, and in fact almost the only representative of the whole family, for only one other species, belonging to a different genus, is known as British, and that is a rare one, having been found only in two localities, and in both cases in towns; so that for all practical purposes, the glowworm may be taken as our one British representative of the family Lampyridæ. The family, in fact, is characteristic of tropical rather than of temperate latitudes.

The family Lampyridæ is one of eight, which are distinguished by their soft and flexible skin, very different from what is found in the majority of the beetle order, which includes the hardest skinned of all insects. This soft-skinned section is called Malacodermata, in consequence of this peculiarity. It is curious that these malacoderms, notwithstanding their soft and yielding skin, are yet fiercely carnivorous. It is pretty easy to recognize a beetle of this section by its very soft body, which often has fleshy protuberances at the side, and its flexible wing covers, which are more or less delicately hairy, and sometimes become slightly distorted by bending and shriveling when the insect is dead. Some of the species are exceedingly beautiful, being bright scarlet, or brilliant metallic green, or exhibiting combinations of the two. The glowworm has no such brilliancy of natural color to recommend it, but makes up for this deficiency by the soft beauty of the greenish glow that appears in its abdomen in the dark.

The sexes of the glowworm are so different that it will be necessary to describe each separately, and we will take the female first, as it is the more familiar. The appearance of the female glowworm is so different

FIG. 1.—FEMALE GLOWWORM, MAGNIFIED TWO DIAMETERS.

from that of adult insects generally, that it is difficult to believe in its maturity, and still more in its being a beetle; in fact, its coleopterous nature would not easily be demonstrable were it not for the appearance of the male. The female (Fig. 1) is an absolutely wingless, grub-like creature, with a small head, which is completely concealed beneath a semicircular projecting scale, representing the dorsal part of the prothorax of an ordinary insect. Behind this scale are ten segments, all except the first and last similar in form, and each broadest behind, so that the edges of the body become saw-like, with ten notches. The first of the ten segments, representing the mesothorax, is more rounded than succeeding ones, and the terminal one, like the prothorax, is semicircular. The color is blackish-brown above, with the margins of all the segments, and some patches in the outer angles of the first two, more or less yellowish or reddish. The whole surface is rough, and covered with extremely short silky hairs. Above, the insect is flat, the dorsal layer of each segment forming a sort of shield projecting at the sides beyond the parts beneath, though not to so great an extent as the semicircular shield which covers the fore part. Each of these trapezoidal shields has a slight ridge down the middle. The under surface is very different, being convex and paler in color; the last three segments are almost white, and it is in these that the glow appears. Three pairs of short legs are carried by the three thoracic segments, and the head bears the usual pair of compound eyes, which are of moderate size, and a pair of short antennæ. As the insect walks, its abdomen trails along the ground, the legs being too far forward and too short to enable it to be raised. It will thus be seen that the insect looks very much like a larva, the thoracic shield being the only characteristic that conveys any other suggestion to a cursory glance.

The female is the only member of the family to which the name of glowworm would popularly be applied. It is usually to be met with in the summer months on grassy or mossy banks, where it lies awaiting the advent of its mate, and showing at night on its under side a greenish glow which proceeds from two bright spots on the last segment, and from the greater part of the two preceding ones. Of course, therefore, the full brilliance of the light can only be seen when the insect is lying on its back. When disturbed it feigns death, curving its abdomen downward and bending up its legs. When left to itself, it is not, as can readily be imagined, a very active creature, and will often remain in the same spot for hours, or it may be days together. In the daylight, owing to the absence of the luminosity, it is seldom noticed except by those who are familiar with its form. In country roads it is sometimes to be met with crawling along near the foot of the hedge, or crossing from one side of the road to the other, and it may also be found underneath stones.

The appearance of the male (Fig. 2) is entirely dif-

FIG. 2.—MALE GLOWWORM, MAGNIFIED TWO DIAMETERS.

ferent, and it is rarely discovered in a similar way to its partner. As it has the ordinary wings and wing covers of a beetle, there is no difficulty in recognizing it as such. But, at first sight, it would not readily be connected with its mate, because the body, wherein lies the chief resemblance, is concealed by the closed wings; but if the elytra and wings are removed, the close resemblance between the two insects is at once obvious. There is the same semicircular shield in front, the same segmented and notched body, with the same distribution of color, and the same short legs and antennæ. It is the wings and elytra that make the male look so different. The elytra or wing covers are long, narrow and parallel sided, entirely concealing the body, and indeed projecting beyond it at both the sides and behind. They are of a grayish brown color, covered all over with minute pit-like depressions, and bounded by a raised rim all round; there are also two or three slightly raised parallel ridges on their surface, and the same clothing of minute and scarcely visible silky hairs covers them as is to be found over the rest of the insect. If we raise these wing covers, we see a pair of smoky wings beneath them about twice as broad as the elytra, and slightly longer, so that they overlap one another when closed, and have to be slightly folded at the tip to get them beneath their covers. The nervures stand out distinctly as dark smoky lines, and at the extreme tip of the wing they meet to form a polygonal area which is destitute of nervures, so as to facilitate the slight folding that has to take place. The insect is a good flier, spreading its elytra, but using only its membranous wings for the purpose of flight. If placed on its back, it is said to right itself by slightly opening its wing covers and thus getting its wings free, and so struggling over by their means. It is nocturnal in habit, and is therefore not often seen unless attracted by light. In places where they are common, an open window with a strong light burning inside will prove an irresistible attraction, and they may be easily caught as they fly toward the lamp.

In all the characteristics we have already described, the male, though so unlike his consort, in no respect differs from the ordinary beetle type. The only point which is at all exceptional is the large size and projecting form of the thoracic shield, but even in this respect the insect is not quite singular; other Coleoptera, such as the tortoise beetles, show exactly the same arrangement. But there is a far more peculiar feature yet to be noticed, and that is the enormous size of the eyes. Of course, these cannot be seen from above, but if the insect be laid on its back, two large, round, black knobs will be seen almost touching one another, just in front of the first pair of legs, and, therefore, under the thoracic shield. (Fig. 3.) A lens shows that they are covered with an immense number of hexagonal facets, and they are thus seen to be the compound eyes. They occupy almost the whole of the head, the mouth organs and antennæ being squeezed into a very very small compass between them in front. As the insect lies in this position, another peculiarity is easily observable. A horny flap from the disk-like thoracic shield bends down on each side of the head, to which it fits so closely that the idea is irresistibly suggested of a broad-brimmed hat placed on the back of the crown and tied beneath the neck by a very wide ribbon. A similar arrangement is made in the female, but as the eyes are not nearly so large, the effect is not so striking.

Luminosity is not the heritage of the female only; the male possesses the power to a slight extent, though his brilliancy is far inferior to that of his mate, and is chiefly confined to the two bright points on the last abdominal segment. Hence the pale area of the ab-

FIG. 3.—HEAD OF MALE GLOWWORM, FROM BENEATH.

domen is not nearly so extensive in the male as in the female, and an inspection of the dead insect even would be sufficient to lead to the conclusion of its far inferior brilliancy. In neither sex is the luminosity an external feature. The seat of the activity which gives rise to the light is internal, and the light merely shines through the transparent skin beneath. The light-producing organs are situated in the last three segments of the body, and consist of two layers of yellowish-white, rounded cells, abundantly supplied with a network of air tubes from the spiracles. The two layers of cells, though similar in form, appear to differ, in constitution and in function, those of one layer only becoming luminous.

It cannot be said that anything very satisfactory has yet been determined with regard to the real cause or nature of the luminosity. According to some careful investigators, it results from a process of oxidation of some of the contents of the luminous cells, produced in them as the result of nervous stimulus. The oxygen required for this purpose, it is maintained, is supplied from the outer air, which, introduced at the very conspicuous spiracles placed at intervals along the sides, finds its way to the light organs through the air tubes. Thus the intensity of the light depends upon the vigor of respiration, supplemented by nervous activity. It is, however, difficult to understand how so bright a light should be produced in this way without any appreciable rise in temperature. The light appears to be, to some extent, under the insect's control, and the advocates of the oxidation theory contend that the regular intermittence of light which is observable in some species is produced by an alternate opening and closing of the spiracles, or at least synchronizes with acts of inspiration and expiration. Other observers, again, while maintaining the oxidation theory, deny that nervous stimulus has any connection with it, and still others deny the oxidation theory altogether.

It is not difficult to determine one function of the light. When one considers the apterous condition, the brilliant light, and the ordinary eyes of the female glowworm, and contrasts with these the winged condition, the feeble light and the enormous eyes of her partner, it is evident that these are complementary features in the two sexes, and there can be little doubt, therefore, that one function of the luminosity is to serve as a sexual attraction, and guide the roving male to his destined spouse. But there is no reason why it should not have other functions as well, and that such is the case would seem to be implied in the fact that the insect is luminous in all its stages, and therefore long before it is sexually mature. The suggestion has been made that the light is protective in function, being a sort of warning signal, like the brilliant colors of certain caterpillars. Considering the softness of the female's skin, and its sluggish habits, it would seem to need more protection than usual, and the suggested use of the luminosity is therefore, at the least, plausible. It is not unreasonable to suppose that a would-be captor would think twice before seizing on so dangerous looking a morsel. On the other hand, the insect is carnivorous, and furnished with a tolerably effective pair of jaws, so that it may perhaps be able to give a better account of itself in a struggle than its soft skin would lead one to suppose.

In confirmation of the sexual function ascribed to the luminosity, the Rev. H. S. Gorham has pointed out that in the family Lampyridæ the eyes are developed in magnitude in proportion to the light displayed; those species that show but a feeble light have but small eyes, and vice versa. The antennæ also are developed in inverse ratio to the light, and it is well known that a great development of antennæ often exists in those insects that can perceive their mates at great distances; thus, when one power of discovery is lessened, another is increased to supply the deficiency. Thus the species may be divided into three groups: first, those with plumose antennæ and small eyes, and with light appearing in small spots only; secondly, those with simple antennæ, larger eyes and a considerable amount of light, both sexes being winged; and thirdly, those with quite rudimentary antennæ, extraordinarily large eyes in the male, and most brilliant light, accompanied by an apterous condition in the female, or, at most, with rudimentary wings in that sex. Evidently, therefore, the light-giving power, eyes, antennæ, and wings, are all related in the progress of their development, and it can scarcely be questioned that such a relation indicates a causal connection.

We may now sketch the life history of this curious insect. Shortly after pairing, the female deposits her eggs. They are of large size and pale in color, and are either placed in the earth or on moss or grass or other low plants, adhering to the spot on which they are placed by means of the viscid liquid with which they are wet. Curiously enough, the eggs are luminous as well as the insect that produced them. It might be thought that, considering where they have come from, this is not to be wondered at, since the

appearance might be due to the moisture that covers their surface. But this is not the case, for if washed in pure water and then dried they still remain luminous. According to Dubois, they may be kept in water for an hour without losing their luminosity, though after the lapse of that time the light begins to wane; but if they are taken out when this occurs, they soon recover their brilliancy. Alcohol rapidly suppresses the luminosity, and boiling water destroys it immediately. The luminosity belongs to the contents of the egg and not to the shell, so that the light shines through the transparent egg-shell. When the egg is hatched, such luminosity as there is appears in the larva, but the empty egg-shell loses every trace of it. Now, since this luminosity appears even in the youngest eggs, before the segmentation of the yolk sets in, it is evident that it is not, in this instance, whatever may be the case with the adult insect, dependent upon nerves or air tubes, or indeed any anatomical element whatever, though, of course, oxygen can pass through the thin egg-shell without any special means of conveyance. The luminosity of the eggs is, however, greatly dependent upon moisture, and gradually disappears as the moss among which they may be lying dries up; it can be restored again, if not too far gone, by the application of moisture.

The larva is extremely like the perfect female, the most noticeable difference being the smaller size of the head shield. It may be found, of various sizes and ages, during the winter and spring, and becomes full-grown about April. The small size of the young larvæ will serve at once to mark their immaturity, since, of course, the adult insect does not grow; but the full-grown larva is less easy to distinguish from the adult female. Besides the shape of the fore parts, there are also minute differences in the feet and antennæ, which aid in their separation. Like the perfect insect, the larva is carnivorous, feeding upon snails, especially those of the genus Zonites or Hellicella, small, flat, shining kinds, often seen under stones, moss, etc., and in damp places generally. At the end of the body it has some seven or eight short white rods, which are usually kept retracted within the body, but can be protruded at will, and these it is said to use for cleansing the fore parts of its body, should any of the snail's slime adhere to it during the course of a meal. The coloration of the larva is a little more distinct and variegated than that of the adult female; the center part of the back is darker, and each segment has a reddish-yellow patch at its exterior angle.

As the insect in its larval stage is so much like the fully developed female, we need not be surprised to learn that the pupa stage is a very short one. Very little metamorphosis, whether internal or external, has to take place, and a very brief time is quite sufficient for this. In little more than a fortnight after the larva has ceased to feed, the perfect insect appears, and the pupa stage itself does not occupy much more than half of this time. The pupa of the female does not differ much in appearance from either the larva or the adult; it remains in a curved position, with legs bent up, very much as the larva or perfect insect would do if feigning death. In the male pupa a difference can be seen; the wings begin to appear, but, of course, as usual, they are of very small size. When the insect is ready to escape from its pupa skin, the latter slits in front, and the beetle wriggles its way out, a soft and nerveless thing. But its skin soon gains strength and consistency, and then it is prepared to atone for its fortnight's fast, by renewing its attacks upon the snails.

It has already been mentioned that the glowworm is not the only member of its family that is found in this country. At Lewes and Hastings another and smaller species has been observed, which is called Phosphænus hemipterus. It is similar in shape to the glowworm, but has considerably longer antennæ. The female is quite apterous, but the male differs markedly from our common species, in that wings are absent, and the elytra are very short, not much more than a quarter as long as the body. Moreover, they are pointed behind, and their inner edges do not meet, but gape apart like those of the oil beetle we described a short time ago. Curiously enough, in this species it is the male that is usually found; the female is either much rarer or manages to keep itself out of sight, for it is very seldom met with. The male is usually found crawling about on walls. This insect is pretty widely distributed on the Continent, but in this country it has been observed only in the two localities above mentioned, though there seems no reason why it should not occur elsewhere.—Knowledge.

OYSTER CULTURE ON THE WEST COAST OF FRANCE.*

AT the request of the Lancashire Sea Fisheries Committee, I spent some time last June and July in investigating the various methods of shell fish culture in use along the western coast of France from Arcachon in the south to Brittany in the north.

There can be no doubt that there are extensive and flourishing shell fish industries along the French coast, and one is struck very forcibly with the admirable manner in which the people seem to make the best of unfavorable conditions, and to take full advantage of any opportunity given to them by nature. Few places on any coast could look more desolate and forbidding than the vast mud swamps of the Bay of Aiguillon, and yet, by means of the "bouchot" system, many square miles of this useless ground have been brought under cultivation and an industry established which supports several villages. Then again, the neat little inclosures along the beach at many places, carefully tended by the owners at low tide, remind one constantly of market gardening, and enforce the truth of the idea long familiar to the biologist, and now beginning to be more generally recognized, that the fisherman should be the farmer, not the mere hunter of his fish, and that aquiculture must be carried on as industriously and scientifically as agriculture.

In addition to industry and care on the part of the fisherfolk, women as well as men, the success of the shell fish industries in France is largely due to the encouragement and wise assistance of the government, especially in the regulation of general oyster dredging and the reservation of certain grounds for supplying seed. The practical question—and one of enormous importance—is: Is there anything special in the conditions in France, either of the land or of the water, which would render their methods inapplicable to our more northern shores? I do not believe that the question can be satisfactorily and finally answered until some experimental cultures on a fairly large scale have been tried. But a consideration of the details and results of the French methods will at least give us some idea of which experiments are worth trying and of the localities which might be cultivated with most prospect of success.

The leading characteristics of French oyster culture are (1) that the whole is under the regulation and supervision of the state, concessions of ground being given to individuals or companies (e. g., at about 30 francs the hectare at Arcachon) for the purpose of forming oyster "parcs;" (2) that certain grounds are set aside or preserved as banks of breeding oysters to supply the spat; and (3) that the whole process of raising the spat, and rearing and fattening the oyster, is not carried on at one locality, but is subdivided and specialized, spat production taking place best at one locality, such as Arcachon, and fattening for market at another, such as Marennes.

Two species of oyster are cultivated, Ostrea edulis, the ordinary rounded flat oyster of northwest Europe; and O. angulata, the elongated Portuguese oyster. The latter, although increasing in numbers in some places, and becoming of considerable commercial importance, is not so highly thought of as is Ostrea edulis.

There are now only two places on the coast of France where spat is produced in sufficient quantity to be of commercial importance. These are Auray, in the north, and Arcachon, in the south, and these two localities supply all the other oyster culture centers in France, and even export to other countries. One merchant I met at Arcachon told me that he had already sent eleven millions of oysters to London that season.* I visited in all about ten different oyster culture centers; but as several of these showed nothing special, they need not be mentioned. The arrangements for the capture and rearing of spat were best seen at Arcachon, and for the further rearing and the fattening of the adults at La Tremblade and Marennes on the estuary of the Seudre. At Arcachon I was fortunate in enjoying the hospitality of the excellent Biological Station, which was established nearly thirty years ago by La Societe Scientifique d'Arcachon, and which was made use of by Paul Bert in 1867 for his observations on the physiology of marine animals.

Arcachon presents remarkable facilities for the study of shallow water marine forms, and is of great interest to the biologist, as well as to the ostreiculturist. Its vast inland sea (Bassin d'Arcachon), which is about 80 kilom. in circumference, contains at high tide about 15,000 hectares of area, and is, over the greater number of the channels, about 5 to 10 fathoms in depth, while two-thirds of the whole area dries at low tide. In the middle of the "bassin," and north of the town of Arcachon, is a small island, Ile des Oiseaux, and on the shores of this, and on various other flat, shallow parts which are exposed at low tide, and which are called "crassats," are situated the oyster "parcs." Some of these areas are reserved by the state for the purpose of producing spat, a wise precaution, although some of the parqueurs think the state reservations unnecessary, as there are so many adult oysters over the ground that plenty of spat is sure to be produced. Certainly during the time of my visit, which was just when the free-swimming embryos were settling down, the water over the parcs seemed to be swarming with them, and the spat was making its appearance over all sorts of suitable submerged objects. The summer of 1893 was, however, a particularly good season, which the parqueurs attributed to the great heat. Probably calm weather and absence of rain during the critical period when the young oysters are free-swimming, and then settling down, has as much to do with a heavy fall of spat as the actual temperature.

The oyster reproduces at Arcachon between May and the beginning of July, and the young animal leads a free-swimming existence for about a week before settling down as spat. The parqueurs examine carefully the condition of the spawn in the old oyster, and at what they consider to be the proper time (generally about the end of June) for catching the deposit of spat, they place their "collectors" in position. It is of importance that the collectors should not be put in the water too soon, as they are liable to become coated with slime and sediment, which will prevent the young oyster spat ("naissain") from adhering. The collectors are crates ("gabarets" or "ruches") of earthenware tiles, coated with a limy cement which gives them a whitewashed appearance. The tiles are like ordinary roofing tiles, about fourteen inches long by six inches at one end and five at the other, and half an inch in thickness. The cement with which they are coated is made of lime mixed with sea water and a certain amount of sand, so as to form a creamy paste. Different proprietors use slightly different proportions of lime and sand. The process of coating ("chaulage") adds from one-sixteenth to one-eighth inch in thickness to each side of the tile. It has to be done with some care, so that the limy layer may be of the right nature, sufficiently strong and adhesive, and yet readily detachable when the time for "detroquage" comes, so that the young oysters may be removed from the tiles without injury, and without the necessity of breaking up the tiles, as used to be the case. By the present method the little oysters and film of cement can be flicked off rapidly by a skilled hand with a square ended knife, and the tiles preserved for use again the following year. A dozen or more millions of these tiles are probably employed each year at Arcachon. The prepared tiles are arranged in alternating rows lengthways and breadthways inside cases made of strips of wood, so that the water may flow in readily between and around them. The cases of collectors I measured were about 6 ft. by 2 ft. and 3 ft. in height, each holding 120 tiles arranged in ten layers. The alternating arrangement of the layers is intended to break up the currents of water as the tide runs through the "ruche," form eddies, and so give the young oysters a better opportunity of affixing themselves to the tiles. The tiles are all placed with the convex surface upward, as it is very important that there should be as little opportunity as possible given for the collection of any fine sediment in which the young spat might be smothered. The arrangement of tiles above described is now considered the best at Arcachon. Various other arrangements have been tried, and may be suited to special conditions of bottom or depths of water.

I was very fortunate in seeing some of the tiles just after the young oyster spat had been deposited, and photographed such a tile covered thickly with the minute amber colored specks. There may be several hundred such young oysters on one side of a tile. During my stay at Arcachon I found that the temperature of the water varied from 74° F. to over 80° F., and the specific gravity from 1·022 to 1·024. However, it is known that no such high temperatures are really required for spat production, since, e. g., Captain Dannevig has had an abundant deposit of spat in his pond near Arendal, in Norway, where the July temperature of the water was only 63° F. To compare these with our own district we find that in the same week of July, 1893, the water off the south end of the Isle of Man was on the average about 60° F., with a specific gravity ranging from 1·025 to 1·026, while shore pools near the Biological Station at Port Erin, comparable as to exposure with the oyster parcs at Arcachon, reached as high a temperature as 76° F. Dr. Bashford Dean* and other authorities state as their opinion that a low specific gravity is necessary for a good deposit of spat, but there is no unanimity on this point among the practical men at Arcachon (some of whom are keen observers, and are in the habit of taking the temperature and specific gravity).

After removal from the tiles, those young oysters which are not sold to "eleveurs" away from Arcachon are kept for another year or two in the parcs. They are placed at first in flat trays having a floor and lid of close galvanized wire netting of about half inch mesh, and these trays ("ambulances" or "caisses ostreophiles") are placed between short posts in the water on the oyster parc, so that the tide can run freely through them, supplying the oysters with food and oxygen. They measure about 6 feet by 4 and are 6 inches deep. They serve to keep the young oyster during the early period of its life out of the sediment, and they also protect it from its numerous natural enemies, such as the starfishes and crabs, which manage to suck or pick out the soft body, and whelks, such as Purpura, Murex and Nassa, which can bore a hole through the shell. The ambulances are constantly looked after by the oyster men and women, who come at low tide when they are exposed, open the lids and pick over the contents, removing enemies and impurities which may have got in, taking out any dead oysters and rearranging those that are left, so that all may have a fair chance of obtaining food and growing normally. The young oysters grow rapidly in the ambulances and soon have to be thinned out. The larger ones are removed, and if large enough are thrown into the open areas of the parc. In this way, by thinning out, rearranging and adding fresh supplies, relays of young oysters in their first year may occupy the ambulances for eight months, although an individual oyster may only be in for a month or so.

Eventually all the oysters not sold to eleveurs get transferred from the ambulances to the open rectangular areas, like little fields, which make up the rest of the parc. The low banks bounding these areas are formed of two parallel rows of close set vertical bunches of the local heath, Erica scoparia, with the space between, a foot or more wide, filled in with masses of a tenacious clay obtained from the Ile des Oiseaux. Planks of wood and stakes to strengthen the boundary are also used in places, and at one corner a sluice is formed, so that the water at low tide may either be retained to a depth of 6 or 8 inches or allowed to run off as required. About one million oysters can be accommodated in each little field, which is about at the rate of 125 to the square meter. Going thoroughly over a parc, partly in a boat and partly by wading, gives one an excellent idea of the extensive and profitable system of aquiculture practiced at Arcachon.

Between neighboring oyster parcs and surrounding the "concessions" of the various proprietors run lanes of water about 4 meters wide. These give ready access to the parcs and can be traversed by the long gondola-like boats of the parqueurs. The lanes are bordered by rows of tall saplings with bunches of twigs left on. These are called "pignons." They kept waving in any slight breeze, and gave a characteristic appearance to the scene. The oyster men declare that they are of use in frightening away fish, and especially the voracious ray Myliobatis, which might otherwise do great damage in the preserves. Possible depredations of another kind are guarded against by the "pontons" or large barges, moored at the corners of the parcs in which the "gardes des peches" live.

Great numbers of the oysters bred and reared through their early stages at Arcachon are sent to Marennes and La Tremblade in the flat district on both sides of the estuary of the Seudre, to be fattened in a parc d'elevage, and "greened" by feeding upon the diatom Navicula fusiformis, var. ostrearia. Wide canals from the estuary lead the sea water inland and supply the numerous "claires," which are merely shallow artificial ponds excavated in the clay and marly soil. In spring and early summer the muddy floor of the claire undergoes a good deal of preparation by digging, cleaning, draining and exposure to sun and air, in order that later on, when sea water is readmitted, at first in small quantity, it may be in what has been found by experience the most favorable condition for the growth of the desired kinds of lower algæ. These soon cover the floor with a dense green growth, which the eleveurs recognize as being of great importance to the nutrition of the oysters. Samples of the growth which I collected from the bottoms of several claires consisted of Cladophora flavescens and C. expansa, along with Spirulina

* Abstract of a report by Prof. W. A. Herdman, F.R.S., to the Lancashire Sea Fisheries Committee.

* Two year olds, measuring 5 to 6 cm. across, cost at the rate of 12 francs per 1,000, and somewhat older ones, measuring 6 to 7 cm., 25 francs per 1,000. These prices include packing and carriage as far as Bordeaux, where they meet the steamer. On an average only 1 per cent. die on the journey. From the middle of March to the middle of April is the best time to send young oysters for stocking purposes to England. Before that it is liable to be too cold in England, and later it is too hot in Arcachon for transportation to be effected safely.

* Various important papers in Bulletin U. S. Fish Commission.

tenuissima and a Lyngbya and little tufts of Calothrix, while a more detailed examination with the microscope shows that these plants are teeming with small animals and other forms of life, and nearly everything is covered with innumerable diatoms. Probably the larger green algæ, thought so much of by the eleveurs, are only of importance in oyster culture in providing points of attachment and shelter or favorable environment for the microscopic forms of life, and especially for the diatoms. It is well known that diatoms form a most important constituent of the food of oysters, and that the greenish blue tint of the celebrated Marennes oysters is due to the presence in the claires of enormous quantities of Navicula fusiformis, var. ostrearia, upon which the oysters feed. This form is found in our own fishery district in the estuary of the Dee (and probably elsewhere), although not abundantly; but it is probable that there are various other allied diatoms that would do equally well for rearing and fattening oysters on, and as a matter of fact the examination of the contents of an oyster's stomach shows that the food consists of a number of different kinds of diatoms, as well as other minute organisms.

Altogether, all the evidence I was able to collect shows, I think, that the bottom of a claire is teeming with microscopic life, and that it is probably this rich feeding alone which is necessary in order to bring the oysters in a very short period—a few weeks usually, sometimes ten days or a fortnight is sufficient—to the desired condition of fatness and flavor. The autumn and early winter months are said to be the best for fattening and greening.

I shall have to omit all reference to the industries at Pointe le Chapus, at the Island of Oleron, at La Rochelle, at Les Sables d'Olonne, and at Le Croisic—except a brief explanation of the basins of "degorgement" seen at Le Chapus and elsewhere. These are shallow tanks, high up on the beach, with smooth bricked or tiled floors, so that they can be kept clean and free from mud. Their purpose is to enable the oysters taken fresh from the parcs and claires, and which naturally have some fine mud and food matters of a decomposable nature clinging to them, both externally and internally, to lie for a few days in clean water, and so get rid of their impure mud and excreta before being packed up and sent off on a journey. The oysters also become accustomed in these basins, which can be emptied and filled with water periodically, to close their shells and stand prolonged exposure to air.

I do not see that the French shores are, in any important respects, better fitted for shell fish culture than some parts of our own Lancashire and Cheshire coast.* The deposits, both littoral and submarine, are, on the whole, much the same, the fauna, both macroscopic and microscopic, is scarcely appreciably richer, and though the temperature of the water is decidedly higher in the south, probably on the average about 10° F. higher in summer, I do not think that that is an essential condition, so long as the winter temperature of our water does not get too low. It would certainly be necessary, I think, to keep our oysters completely submerged during the winter months; but there are several places in the estuaries of the Dee and the Ribble, and in the Barrow Channel near Roe and Peil Islands, where "littoral" cultivation in summer might be combined with "bedding out" in winter—somewhat as is done at present with American oysters in the estuary of the Wyre, near Fleetwood. As to the other conditions—of bottom, of water, and of food, several places in the Barrow Channel and in the Dee estuary seem to me to be well fitted for oyster culture.

GALVANIZING.†

By Mr. M. P. WOOD.

GALVANIZING as a protecting surface for large articles, such as enter into the construction of railway viaducts, bridges, roofs and ship work, has not reached the point of appreciation that possibly the near future may award to it. Certain fallacies existed for a long time as to the relative merits of the dry or molten and the wet or electrolytical methods of galvanizing. The latter was found to be too costly and slow, and the results obtained were erratic and not satisfactory, and soon gave place to the dry or molten bath process as in practice at the present day; but the difficulty of management in connection with large baths of molten material, the deterioration of the bath and other mechanical causes, limit the process to articles of comparatively small size and weight.

The electro-deposition of zinc has been subject to many patents, and the efforts to introduce it have been lamentable failures in both a mechanical and financial sense. Most authorities recommend a current density of 18 or 20 amperes per square foot of cathode surface and aqueous solutions of zinc sulphate, acetate or chloride, ammonia, chloride or tartrate, as being the most suitable for deposition. Herman's process has been experimented with on a commercial scale, the chief feature being the addition of the sulphates of the alkalies or alkali earth to a weak solution of zinc phosphate.

Electrolytes made by adding caustic potash or soda to a suitable zinc salt have been found to be unworkable in practice, on account of the formation of an insoluble zinc oxide on the surface of the anode and the resultant increased electrical resistance; the electrolytes are also constantly getting out of order, as more metal is taken out of the solution than could possibly be dissolved from the anodes by the chemicals set free on account of this insoluble scale or furring up of the anodes, which sometimes reaches ⅛ inch in thickness.

To all intents and purposes the deposits obtained from acid solutions under favorable circumstances are fairly adhesive when great care has been exercised to thoroughly scale and clean the surface to be coated, and which is found to be the principal difficulty in the application of any electro-chemical process for copper, lead or tin, as well as for zinc, and that renders even the application of paint or other brush compounds so futile unless honestly complied with. Unfortunately, these acid zinc coatings are of transitory nature, their durability being incomparable with hot galvanizing, as the deposit is porous and retains some of the acid salts, which cause a wasting of the zinc and consequently the rusting of the iron or steel. Castings coated with acid zinc rust comparatively quickly, even when the porosity has been reduced by oxidation, aggravated no doubt by some of the corroding agents, sal ammoniac, for instance, being forced into the pores of the metal.

Other matters of serious moment in the acid electro-zincking process, aside from the slowness of the operation, were the uncertain nature, thickness and extent of the coating on articles of irregular shape, and the formation of loose, dark colored patches on the works; the unhealthy, non-metallic look and want of brilliancy and luster prevented engineers and the trade from accepting the process or its results, except for the commoner articles of use. The Cowper-Coles process of electro-zincking articles claims to overcome all these difficulties, and plants are in process of erection with a bath of some 14,000 gallons capacity, capable of turning out 40 tons of light work per week, and in which it is proposed to treat the plates of vessels 60 feet in length upon one or both sides, and the frames of such vessels as torpedo boat destroyers and kindred craft after riveting up. These plates and frames are given a thin coating of zinc by this process that appears to be perfectly uniform in character and extent, whatever the shape of the piece may be and however numerous the lugs, flanges, mortises or core holes, and is called "zinc flashing"—that is, coating the iron or steel article, after picking and cleaning, with a thin coat of zinc about one ounce per square foot of surface, which resists the inclemency of the weather and mechanical injury as well as a thicker coat, and is found to afford sufficient protection in most cases, and is adequate protection until such time as it is ready to receive the usual paint coatings.

To obviate any tendency of the paint to peel off from the zinc surfaces, as it generally manifests a disposition to do, it is recommended to coat all the zinc surfaces, previous to painting them, with the following compound:

One part chloride of copper, one part nitrate of copper, one part sal ammoniac, dissolved in 61 parts of water and then add one part commercial hydrochloric acid.

When the zinc is brushed over with this mixture it oxidizes the surface, turns black, and dries in from 12 to 24 hours, and may then be painted over without danger of peeling. Another and more quickly applied coating consists of bichloride of platinum 1 part dissolved in 10 parts distilled water and applied either by a brush or sponge. It oxidizes at once, turns black, and resists the weak acids, rain and the elements generally.

Zinc surfaces, after a brief exposure to the air, become coated with a thin film of oxide—insoluble in water—which adheres tenaciously, forming a protective coating to the underlying zinc. So long as the zinc surface remains intact, the underlying metal is protected from corrosive action, but a mechanical or other injury to the zinc coating, that exposes the metal beneath in the presence of moisture, causes a very rapid corrosion to be inaugurated, the galvanic action being changed from the zinc positive to zinc negative, and the iron as the positive element in the circuit is corroded instead of the zinc. When galvanized iron is immersed in a corrosive liquid, the zinc is attacked in preference to the iron, provided both the exposed parts of the iron and the protected parts are immersed in the liquid. The zinc has not the same protective quality when the liquid is sprinkled over the surface and remains in isolated drops. Sea air, being charged with saline matters, is very destructive to galvanized surfaces, forming a soluble chloride by its action. As zinc is one of the metals most readily attacked by acids, ordinary galvanized iron is not suitable for positions where it is to be much exposed to an atmosphere charged with acids sent into the air by some manufactories, or to the sulphuric acid fumes found in the products of combustion of rolling mills, iron, glass and gas works, etc., and yet we see engineers of note covering in important buildings with corrugated and other sheets of iron and using galvanized iron tie rods, angles and other construction shapes, in blind confidence of the protective power of the zinc coating; else in supreme indifference as to the future consequences and catastrophes that arise from their unexpected failure.

The comparative inertia of lead to the chemical action of many acids has led to the contention that it should form as good if not a better protection to iron than zinc, but in practice it is found to be deficient as a protective coating against corrosion. A piece of lead-coated iron or terne plate placed in water will show decided evidences of corrosion in 24 hours. This is to be attributed to the porous nature of the coating, whether it is applied by the hot or wet (acid) process.

The lead does not bond to the plate as well as either of the other metals, zinc, tin, copper or any alloys of them. The usual weight of lead-coated terne plates is about ¾ ounce to a square foot, while hot process zinc coatings weigh from 1½ ounces minimum to 8 ounces maximum, depending upon the temperature of the bath, and the slowness of removal therefrom giving time for the article to drain off. The following table gives the increase in weight of different articles due to hot galvanizing:

Description of article.	Weight of zinc per square foot.	Percentage of increase of weight.
Thin sheet iron = 0·026 inch No. 22 B. W. G.	1·196 ounces.	18·2
1/16 inch plate............	1·76 "	2·00
4 inch cut nails	2·19 "	6·73
⅞ inch die bolt and nut..................	approximately 1·206 ounces.	1·00

Tin is often added to the hot bath for the purpose of obtaining a smoother surface and larger spangles or facets, but it is found to shorten the life of the protective coating considerably. A portion of a zinc coating applied by the hot process was found to be very brittle, breaking when attempts were made to bend it; the average thickness of the coating was 0·015 inch.

An analysis gave the following result:

Tin....................................	2·20
Iron....................................	3·78
Arsenic....................................	Trace
Zinc (by difference)	94·02

A small quantity of iron is dissolved from all the articles placed in the molten zinc bath, and a dross is formed amounting in many cases to 25 per cent. of the whole amount of zinc used. This zinc-iron alloy is very brittle, and contains by analysis 6 per cent. of iron and is used to cast small art ornaments from. A hot galvanizing plant having a bath capacity of 10 × 4 feet × 4 feet 6 inches outside dimensions, and about 1 inch in thickness, will cost $625 and will hold 28 long tons of zinc, which at 4 cents per pound will require $2,500 to fill it. The heating of this mass of metal and its ever-changing cold immersions, with the waste by dross and extra thickness in spots, is a constant source of annoyance and expense.

The cost of an electro-chemical or wet bath Cowper-Coles plant of 6,700 gallons bath, size 30 × 6 feet × 7 feet, will be but slightly more than the hot bath given. There is no dross formed by the use of the Cowper-Coles process, and the zinc coating formed is said to resist the corroding action of a saturated solution of copper sulphate—English Post Office test for telegraph wire—much better than hot galvanized iron wire, as per following table:

RESULT OF PROCESS TEST MADE ON SAMPLES OF CHARCOAL IRON WIRE COATED WITH ZINC BY VARIOUS PROCESSES.

Process used to test the iron.	Grains of zinc per square foot.	Ounces per square foot.	No. of 1 minute dips; samples stood without showing metallic copper.
Hot galvanized.........	648·5	1·48	3
Acid bath $ZnSO_4$.......	446·4	1·02	4
Cowper-Coles process...	532·64	1·23	5

A Cowper-Coles process bath of a capacity of about 4,000 gallons will treat ship plates 18 feet long, and will require an electrical energy of 2,000 amperes of 5 volt electromotive force.

With equal amounts of zinc per unit of area, the zinc coating put on by the cold process is more resistant to the corroding action of a saturated solution of copper sulphate than is the case with steel coated by the ordinary hot galvanizing process; or, to put it in another form, articles coated by the cold process should have an equally long life under the same conditions of exposure that hot galvanized articles are exposed to, and with less zinc than would be necessary in the ordinary hot process. The hardness of a zinc surface is a matter of some importance. With this object in view, aluminum has been added from a separate crucible to the molten zinc at the moment of dipping the article to be zincked, so as to form a compound surface of zinco-aluminum, and to reduce the ashes formed from the protective coverings of sal ammoniac, fat, glycerine, etc. The addition of the aluminum also reduces the thickness of the coating applied.

Cold and hot galvanized plates appear to stand abrasion equally well. The thickness of the coating being the same, tests by means of the sclerometer show: Cold galvanized sheet, 6°; hot galvanized sheet, 6°; terne plate, 2°; tin plate, 2°. The figures represent the load in grammes upon a diamond point, just sufficient to cause it to scratch the specimen. The attempts to electro-zinc iron and steel wire for wire standing rigging, bridge or other cables, have not been successful; it has not been found practical to produce a wire capable of withstanding more than one immersion in a copper sulphate solution.

Both pickling and hot galvanizing reduce the strength, distort and render brittle iron and steel wires of small sections. Zinc fuses at 775° F., and the bath is usually kept at about 1,000° F. Steel wire of high breaking strain has its hardness, and consequently its ultimate tensile strength and elongational efficiency, reduced by drawing of the temper and the formation of an iron-zinc alloy on the surface of the wire, by as much as from 5 to 10 per cent. It is the practice when coating steel wire to keep the bath at as low heat as possible and to run the wire through it at a high rate of speed. Both these operations lead to a waste of zinc by reason of the rapid solidification of the metal on the comparatively cold wire, and consequently the ready breaking or cracking off of the covering metal on bending or twisting it, owing to the difficulty with which molten zinc adheres to the steel, except after long contact in the bath. In some cases the wire is wiped between asbestos rubbers as it leaves the bath; but wire thus treated is found to resist corrosion but a very short time.

The English manufacturers have ceased galvanizing their high grade steel wire that cost some $175 per ton, on account of the great risk of rendering it worthless, which is clearly a disadvantage, although the advisability of protecting the steel is unquestionable, as corrosion is found to be very marked on the inner strands of ropes or cables formed from uncoated wires. The Cowper-Coles or cold galvanizing process is in operation at the works of the Laird Brothers, Birkenhead, England, and used for the purpose of zincking the skin plates and frames of the torpedo boats and torpedo boat destroyers built by them for the English navy.

A FRENCH mathematician calculates that in certain watches the motions—which in all are effected in little equal jumps—exceed 200,000,000 a year, and that the outside of the average balance travels 7,500 miles in the same time. Quite as astonishing is the insignificance of the power consumed, one horse power being sufficient to run 270,000,000 watches, or probably all that are in existence.

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* This, being a report to the Lancashire Sea Fisheries Committee, is only concerned with localities within the fishery district.

† Abstracted from a paper prepared for the American Society of Mechanical Engineers.

THE SIPHON OF CLICHY-ASNIERES.

THE siphon of Clichy-Asnieres, constructed under the Seine by Mr. J. Berlier, was inaugurated on Sunday, November 11, 1894. This siphon, which is no less than 1,520 feet in length, is the first section of what is called the Acheres aqueduct, proclaimed to be of public utility by a law of April 4, 1889. It forms part of the material realization of the vast and so warmly discussed programme of the "Tout à l'Egout." The sewage water of Paris, at present emptied into the Seine by the Asnieres collector, will, after the aqueduct is finished, be thrown into the siphon under consideration through a vertical well excavated at Clichy. It will pass under the Seine, as shown in Fig. 1, and reappear upon the left shore, at Asnieres, in the open aqueduct that forms a continuation of the system and which will be able to discharge 340 cubic feet per second. The siphon is situated at 52 feet below the level of the Seine. Fig. 2 shows the work that the laborers have executed here.

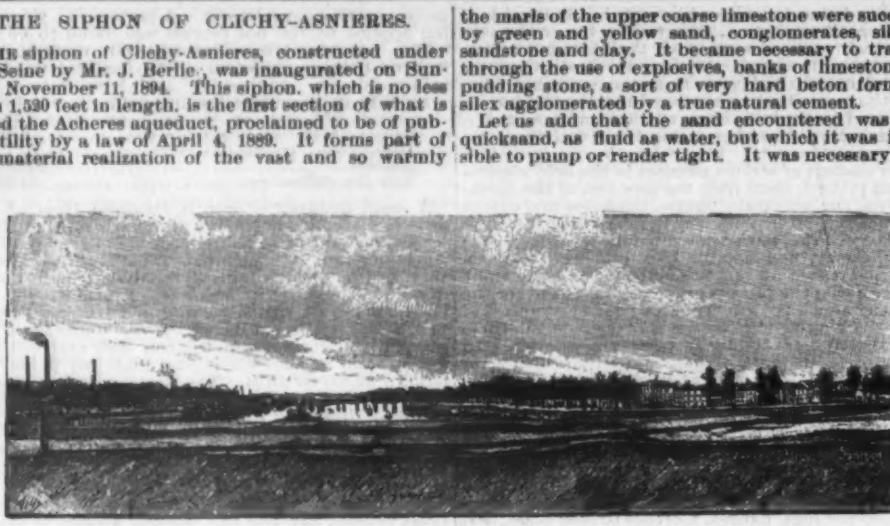


FIG. 1.—THE CLICHY-ASNIERES SIPHON—GENERAL VIEW OF THE CONDUIT UNDER THE SEINE.

We have already had a few examples of similar work in foreign countries. Two tunnels of this kind pass under the Thames at London, and one under the Mersey. In the United States there are the Hudson and Saint Clair River tunnels. But in France nothing of the sort had as yet been attempted. Mr. J. Berlier, a civil engineer, nevertheless became surety for the success of it, and undertook the Clichy-Asnieres siphon at his own risk and peril.

The work was very difficult, since at this place the bottom of the Seine is extremely uneven. The river, in excavating its bed at a remote epoch of geological history, profoundly disturbed the earth, and fissures were formed that were afterward filled in with all sorts of materials. So the borings that were made at the inception of the enterprise furnished our engineers with nothing but vague data. The ground changed from one yard to another as an advance was made; muddy alluviums were mixed with sandy ones; and the marls of the upper coarse limestone were succeeded by green and yellow sand, conglomerates, siliceous sandstone and clay. It became necessary to traverse, through the use of explosives, banks of limestone and pudding stone, a sort of very hard beton formed of silex agglomerated by a true natural cement.

Let us add that the sand encountered was often quicksand, as fluid as water, but which it was impossible to pump or render tight. It was necessary to remove it by hand, so as not to produce interminable cavings in front of the cutting. At many points, too, the marl, although compact enough to hold the water, was fissured and allowed true torrents of the liquid to pass.

In order to overcome these innumerable natural difficulties, Mr. Berlier operated constantly in compressed air, the pressure of which reached as high as three atmospheres. The piercing was effected by what is called the shield method, which had given good results in various analogous cases in other countries, especially in the tunnels under the rivers Thames and St. Clair.

FIG. 2.—WORK EXECUTED IN THE GALLERY UNDER THE SEINE.

As we have already spoken of this method, we shall here merely recall the principle of it, which has been simplified, and "Frenchified," as it were, by Mr. Berlier.

The shield was employed for the first time under the Thames by Brunel, a French engineer, in 1825, but this shield was of wood, rectangular in shape and 40 feet in width by 23 in height. Elbow levers caused it to advance against the earth that was to be excavated in front of it. The masonry lining of the gallery was built up behind in measure as an advance was made.

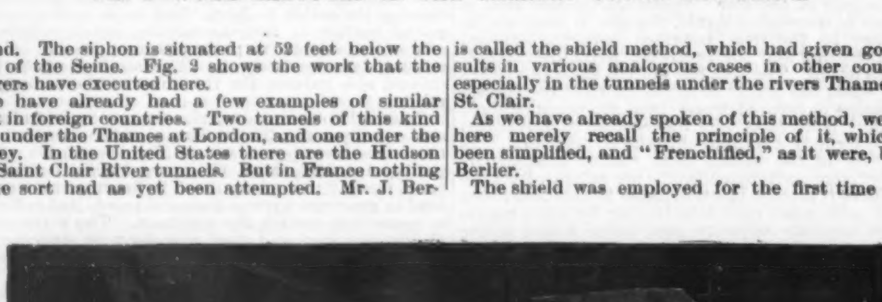


FIG. 3.—MOUTH OF THE SHAFT LEADING TO THE TUNNEL.

The present shield is metallic and of circular section. Its diameter at the siphon of Clichy-Asnieres is 8 feet—slightly wider than that of the gallery to be opened (Fig. 4). It is provided in front with a steel cutting edge, or knife, which cuts out the earth. This earth is removed through doors in the diaphragm constituting the shield. The shield, which is 4 feet in length, is provided in the rear with a cylindrical prolongation having an internal diameter of 8 feet, so as to inclose the conduit after the manner of telescope tubes. The length of this prolongation is 2 feet, say a little more than once the length of one of the cast iron rings of which the conduit is composed. It therefore forms in the rear of the shield a sort of lining in which it is possible to proceed with the mounting of the siphon.

The shield is pushed forward by means of five hydraulic jacks fixed to its periphery, and the piston of which, provided with a large cast iron head, takes its bearing point upon the part of the siphon already constructed. After the shield has advanced about twenty inches, a perfectly circular excavation has been made. The pistons of the hydraulic jacks are then drawn back into their cylinders, and the mounting of the flanged cast iron rings that are to form the final lining is proceeded with. These rings, which are 20 inches in length and 1 inch in thickness, are smooth externally and provided with assembling flanges in the interior. Each of them is composed of five identical plates, and one smaller one forming a key.

In advancing, the telescopic part of the shield leaves an irregular annular space of about 12 inches around the conduit. This space is filled in with mortar in an ingenious manner, so as to obtain a true external shell. To this effect, an iron plate reservoir, provided with a mixer, is filled with the mortar. From its lower part runs a flexible rubber tube ending in a nozzle that fits into apertures formed in the center of each plate and threaded. Compressed air is admitted into the reservoir, and the mortar, forcibly expelled to the exterior, becomes distributed throughout the annular space, which it fills and in which it becomes moulded. The operation is begun with the apertures of the lower plates. When the mortar appears at the upper apertures the nozzle is fitted thereto, while the apertures of the plates already covered are closed with wooden plugs. Moreover, here and there, externally to the siphon, a small circular wall is established in order to prevent the mortar, during the injection, from running toward the front part in process of excavation.

The rings are coated internally also with cement.

FIG. 4.—THE SHIELD, WITH MEN AT THE LEVERS OF THE HYDRAULIC JACKS.

It is well to state that for this purpose there is used a cement prepared with blast furnace slag, and which appears to give very good results.

At the time of the inauguration the visitors were enabled to assure themselves that there was no infiltration of water into the siphon. There was nothing to be perceived upon the walls but the condensations of aqueous vapor that are inevitable in all tunnels.

The visitors were let down in the cage shown in Fig. 3, which gives a view of the mouth of the shaft.

We shall say but a few words about this vertical shaft that gives access to the siphon. It is 78 feet in depth and 9½ in diameter. Its lining consists of iron rings 3¼ feet in width and one inch in thickness cast in a single piece and provided with flanges for the reception of assembling bolts. In plan the direction line of the work includes two great straight alignments connected by a curve of 328 feet radius. It presents two successive gradients, the first of $\frac{1}{16}$ inch to the foot under the river and the second of $\frac{1}{16}$ inch to the foot under the left shore.

It is unnecessary to say that a much greater diameter can be given to the shield than that adopted for the Clichy-Asnieres siphon. Diameters of 20 or more feet are practicable. For the Saint Clair tunnel the diameter of the shield was 21 feet. Mr. Berlier proposes to use the same system for the construction of the city railway decided upon between the Bois de Boulogne and Vincennes and also for the tunnel under the Seine, for a long time demanded, between Havre and Pont Audemer for the passage of the traffic of the Company of the East. The excellent conditions of execution of the Clichy-Asnieres tunnel allow one to think that these two important works also might be effected without any exceptional difficulties for our engineers.

The work on the siphon was executed under the direction of Mr. Bechmann, engineer in chief, and Launoy, engineer of the health department of Paris, by Mr. Berlier himself, who had, under his orders, Mr. Amiot as engineer in chief of service. The courage and persistence displayed by these engineers and the workmen did not remit for a single instant, notwithstanding the difficulties of all kinds that they met with. So the construction of this work will remain as an interesting and honorable episode in the history of the art of public work in France.—La Nature.

INCREASING USE OF TRACTION ENGINES.

THE successful employment of the traction engine in heavy work is most effectively illustrated in the logging business of the Siskiyou Lumber Company, at Sisson, Cal., as shown in our engraving, made direct from a photograph. It is said the grades traveled over are also much steeper than it has been usual, heretofore, to attack with traction engines, but that the work is in every way successfully performed. The engine shown was made by the Best Manufacturing Company, of San Leandro, Cal., and many of these engines are now being used in California for agricultural purposes, freight hauling, etc. As the engine is three-wheeled, it can be turned in as short a space as a two-horse wagon. The starting, steering and reversing of engine, and pumping of water, are all done by one man without leaving his seat. The drive wheel tires are of steel, and the height of the wheels of the 50 horse power engine is 8 feet; the width of the tire 26 inches. The engine is supplied with a windlass for hauling logs out of canons and other inaccessible places, this also being operated by the engineer from his place on the engine.

One of these engines is reported to be employed in hauling freight between Farmington and Stockton, Cal., on a road parallel with the railway and at the same rates, its owner thus doing a large and profitable business. The saving effected by their use in all kinds of agricultural work is something remarkable, the figures given for plowing, harrowing, and seeding, with the aid of these engines, being as low as 60 cents per acre, while, with the aid of a steam harvester, it is said that grain may be cut, thrashed, recleaned, and sacked ready for the mill at a cost of but 30 cents per acre.

Another of our engravings shows a train of lumber-loaded wagons drawn by one of these locomotives. The ease with which the train is drawn over rough roads and heavy grades is surprising.

TRACTION ENGINE USED FOR LOGGING PURPOSES IN CALIFORNIA.

ENGINEERING FALLACIES.*

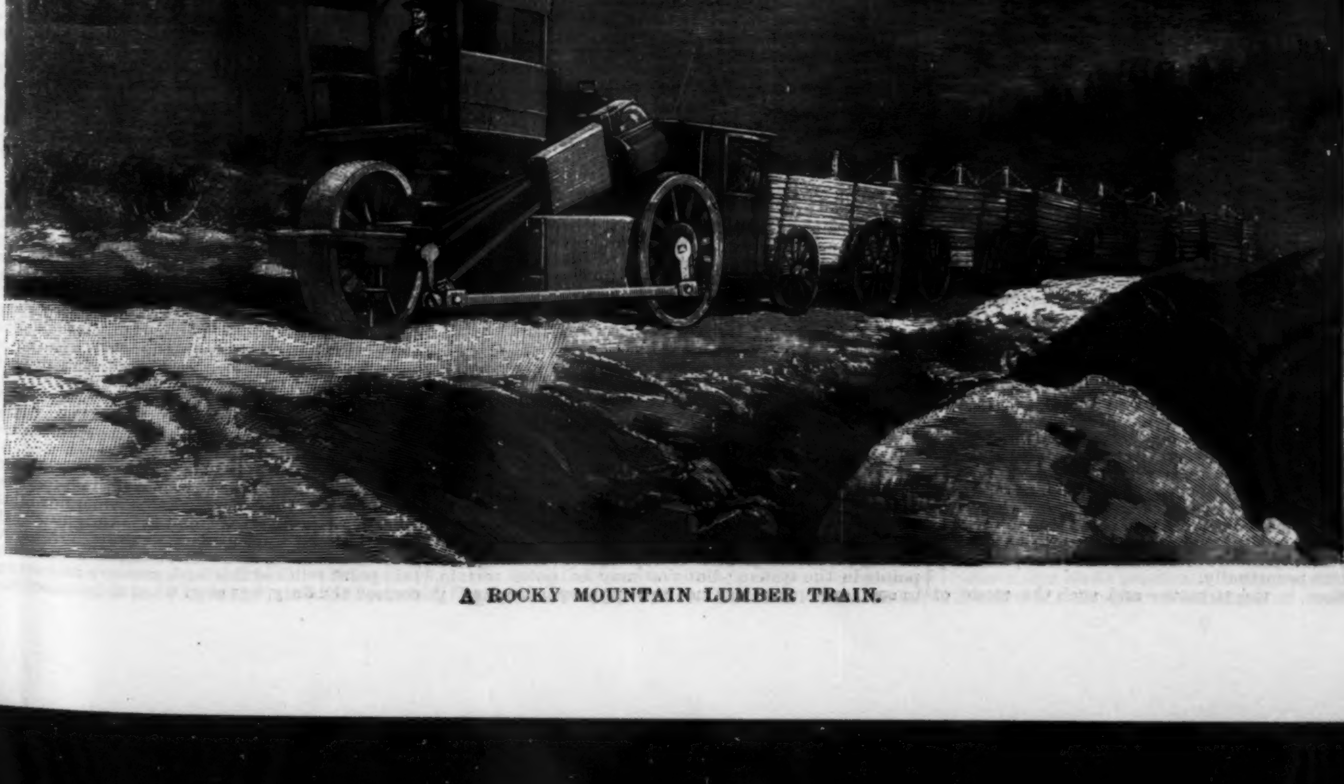
GENTLEMEN OF THE GRADUATING CLASS: There are a number of popular fallacies which, as mechanical engineers, you are likely to encounter in the course of your professional work, and which, as experience has shown, may sometimes lead even able men astray when met with in a new guise, and which are also occasionally not easy to expose or explain to the ordinary observer. As my own experience during the last thirty years has brought me in contact with quite a number of these, I believe that I may do you a service by reviewing some of my experiences, and by calling your attention to some general principles or rules for dealing with such subjects which I have found eminently useful.

In the first place, though it may seem almost superfluous to mention such a thing, every engineer or investigator who undertakes the examination of any new project involving an assumed discovery of new laws or modes of action among the forces of nature, must hold with absolute confidence the great doctrine of the conservation of energy, with its direct corollary relating to what is technically called perpetual motion.

This doctrine may be briefly stated as follows:

No item of energy in the universe ever perishes, nor is any item of energy ever added to the existing supply; the only changes possible are the transformations of energy from one form into another. Thus heat energy may be developed from electrical energy, or from chemical energy, or from mechanical energy, but for every unit of heat energy developed, an

* An address to the graduating class of the Stevens Institute of Technology.—From the Stevens Indicator, by President Henry Morton.



A ROCKY MOUNTAIN LUMBER TRAIN.

exact equivalent of the other form of energy must disappear.

Proteus-like, energy can take all shapes, but must leave one to assume another.

It can only transform, and can in nowise multiply itself.

It is just as impossible to create energy as to create matter, and if any process is presented which claims to get out of a pound of coal more energy than it is known to possess, or out of the work of a horse more than its known amount, it should be regarded as precisely equivalent to the claim that ten chairs could be made into eleven or twelve by some special grouping or arrangement of them.

In other words, we should regard it as either a piece of legerdemain or of oversight and error of observation.

In one of its simplest forms of application this principle amounts to the familiar statement of the impossibility of "perpetual motion."

It may be well to remark here that this term, as used in this connection, does not mean indefinitely continued motion; for this, where no resistance is encountered, might manifestly exist, and may be said to be illustrated by the heavenly bodies.

Perpetual motion means the doing of work without expenditure of energy, as would be illustrated by a machine which once started would continue to saw wood or even overcome the friction of its own journals without further supply of energy.

Strange as it may seem, even in this crude form this fallacy still crops out, and I have within a year encountered it among intelligent and, in a general sense, well educated people, and I will therefore venture on a word of suggestion as to the best means of treating such cases.

In the first place, as a rule at the present time, even those who suppose they have discovered a means of creating energy, by the use of mechanism, do not go so far as to suppose that a machine can move itself, but only believe that by certain combinations a given amount of energy or work may be developed or increased into a larger amount, and in such cases the best argument to open their eyes to the fallacy of their plan is the reductio ad absurdum which will be reached by suggesting the connection of the end of their mechanism where the increased "power" is supposed to be available with the starting point where the small driving force is to be applied.

Thus, suppose an inventor of this sort comes to you with a train of wheelwork, levers, etc., by which one man is to propel a train of cars or the like.

It is generally useless to follow out the steps of the mechanism and to point out exactly where a false assumption has been made. If he can appreciate the point at all, he will consider it simply as a matter of detail which he will be able to improve on further study; but if you pick out the final wheel which is to give motion to the whole train of cars, he will, of course, admit that it will turn around with many times more power than a man could exert.

You will then propose that this should be connected directly with the crank or lever at which the man was to work, when it would manifestly do the man's work and have a large amount of power left over to run the train, thus dispensing with the man's services as soon as he had started the apparatus, and making the machine self-driving.

In curable cases, where no fraud is involved, this will be sufficient; but, too often, the inventor of a perpetual motion machine is beyond the reach of reason, as was the case with the one who came to Arago for an explanation of the fact that his perpetual motion machine would stop.

Not infrequently such plans involve a mechanical fraud by which the driving force is conveyed to the visible mechanism from a concealed source of power.

In such cases there is an opportunity of applying close and inclusive observation and some ingenuity in order to detect the fraud.

An admirable instance of this is furnished by the history of a small model in the collection of the Franklin Institute, at Philadelphia, which was made about eighty years ago by Isaiah Lukens, at the suggestion of Mr. Nathan Sellers, for the purpose of exposing the fraud involved in the then famous Readhefer perpetual motion machine, in which large sums of money were sunk, as they have been in the "Keely motor" and like schemes more recently.

The model consists of a horizontal circular table, attached to and supported by a central vertical shaft, resting on a pivot below and steadied by a journal held in a framework above. Two inclined planes mounted on wheels rest on this circular table, and each inclined plane has on it a car containing two removable weights.

The inclined planes, and also the cars, are attached to levers which are supposed to transmit to the central shaft the tendencies of the inclined planes to run from under the cars and of the cars to run down the inclined planes, and these tendencies are supposed to cause rotation of the central shaft, carrying with it the table and all the parts on it.

This arrangement is admirably simple in more senses than one, but, wonderful to relate, it seems to work.

If the weights are taken out of the cars, the machine comes to rest, but starts up again as soon as they are replaced, and under favorable conditions will continue to run indefinitely.

Here is a phenomenon which might well startle a novice, but he would do well to hold fast to his faith in the conservation of energy and insist on a further investigation into the interior of the apparatus, for this is what such an investigation would reveal:

A train of clockwork driven by a spring is concealed in the base of the machine, and can be wound up by a slight motion of one of the ornamental knobs on the frame of a glass case which covers and locks up the model beyond seeming possibility of tampering.

This clockwork drives a small plate on which rests the pivot of the central vertical shaft, and the various frictions are so adjusted that when the cars are loaded the weight so given will make the friction of the little plate sufficient to drive the shaft, but when the weights are removed this friction is too slight. An attendant once a day touching the outside case for a moment, under pretense of dusting or the like, can keep it wound up perpetually.

Such, then, is the structure and such the mode of operation of this very ingenious model, whose history, which is also extremely interesting, I will now give.

In the year 1812 Mr. Readhefer applied to the legislature of Pennsylvania for a grant of funds to carry out his great invention of perpetual motion, and a committee of experts, consisting of Messrs. Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wermerag, Josiah White, and Samuel D. Ingham, was appointed to examine the matter.

The machine to be examined was set up in a building near the banks of the Schuylkill River in Philadelphia; and on a day appointed, the above-named commissioners went out to inspect the apparatus, Mr. Nathan Sellers taking with him his son, then a lad, but afterward the father of Prof. Coleman Sellers, E. D.

When the commissioners arrived at the location, they found that the door of the room containing the machine was locked, and the key missing, so that their study was confined to an inspection of the apparatus through a barred window.

Even this limited view, however, was enough for the sharp eyes of young Coleman Sellers. The machine had a set of teeth on the periphery of the rotating table which geared into another wheel whose axle was supposed to transmit the power to some other point where work was to be done.

Young Sellers, looking through the window, noticed that the faces of the teeth in the two wheels were polished by wear on the wrong sides.

This will be clear from a glance at the accompanying diagram, Fig. 1.

Let A be the rotating table driving the gear wheel, B, in the direction of the arrows; then, clearly, the front faces of the teeth of A will press against the rear faces of the teeth of B, and these faces will be polished by friction.

If, however, it is the front faces of the teeth of A and the rear faces of those of B that are polished, it is manifest that B must be driving A. This is what young Sellers noticed and pointed out to his father as proving that the perpetual motion machine, in place of driving the gear wheel, was being driven by it from some concealed source of power.

Satisfied as to the fraudulent character of the Readhefer machine by this observation, Mr. Nathan Sellers concluded that others might be best satisfied by a sort of homeopathic object lesson.

He therefore went to Mr. Isaiah Lukens, a very skillful mechanician of that date, and had him construct the model above described. This he at first exhibited to a number of persons, including Mr. Readhefer himself, without explaining its "true inwardness."

Mr. Readhefer was so impressed that he privately offered Mr. Sellers a large share of his inventions if he would tell him "how it was done."

It is hardly necessary to say that this offer was declined, and the true modus operandi in due time made public.

This matter is so curious in many respects that I will here read a copy of the resolution under which this commission acted:

Whereas, The interference of the legislature of Pennsylvania in causing an inquiry to be made relative to the perfection or imperfection of newly invented machinery is not without precedent; and

Whereas, It has been represented that Charles Readhefer, of the County of Philadelphia, has invented a machine declared not only by the inventor, but by many intelligent persons, to possess the power of self-motion; and

Whereas, Should it be ascertained that these opinions are correctly founded, not only great honor would be conferred upon the commonwealth, but incalculable advantages would be derived from the invention by the people of the United States especially, and by mankind in general; and

Whereas, On the other hand, should the machine be found to be imperfect, the public interest would be promoted by exposing its fallacy; and

Whereas, The legislature of this commonwealth reposes confidence in the integrity and qualifications of Henry Voight, Robert Patterson, Nathan Sellers, and Oliver Evans, of the City of Philadelphia; Archibald Binney, Lewis Wermerag, and Josiah White, of the County of Philadelphia; and Samuel D. Ingham, of the County of Bucks; therefore

Resolved, By the Senate and House of Representatives of the Commonwealth of Pennsylvania, in General Assembly met, that Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wermerag, Josiah White, and Samuel D. Ingham be and they are hereby requested to make a strict examination of the machine invented by Charles Readhefer, and to make specific representation respecting it as its alleged importance and the public expectation require.

Resolved, That the secretary of the commonwealth be, and is hereby, requested to transmit a copy of the foregoing preamble and resolution to each of the persons named therein, and also to Charles Readhefer.

(Sig.) JOHN TOD,
Speaker of the House of Representatives.
P. C. LANE,
Speaker of the Senate.

In the House of Representatives,
December 14, 1812.
Read and adopted.
GEORGE HECKERT,
Clerk of the House of Representatives.
In Senate, December 17, 1812.
Read and adopted.
JOSIAH A. MCJIMSEY,
Clerk of the Senate.

Then follows the certificate of the deputy secretary, and his letter to Nathan Sellers.

The driving of a supposed motor through machinery which is supposed to be driven by it is a very general method of deception.

Thus I have seen one of these supposed "motors" set up in a shop and connected by belting and shafting with a number of lathes and other machine tools. When everything was running it was impossible by mere inspection to say which may have been the real "driver," since the power might have been transmitted through a hollow journal to any one of a number of points in the system; but you may be quite certain, in such cases, that it is not the supposed "motor," if the conditions of its operation are inconsistent with the doctrine of "conservation of energy."

In the case of these fraudulent structures a fortunate accident may aid detection.

About twenty years ago a Mr. Paine had an electro-magnetic engine in Newark, in which many persons whose names are not unknown to fame, and who certainly ought to have known better, "took much stock" in the literal as well as figurative sense.

Being in Newark on some other business, I was waited upon by Mr. Paine and invited to see the machine. I accepted the risk (which I will presently explain) attending such a visit, and went with him.

The apparatus was shown off with great success, starting with full velocity the moment a connection was made with a little battery of four cells, driving lathes, sawing wood, etc., in a way that demonstrated several horse power at least. I need hardly say that I was not convinced that perpetual motion had been discovered, but only looked out for the trick.

Nothing, however, could be demonstrated without taking the ponderous machinery to pieces. Near the end of my visit, however, in connection with a pseudo explanation of some point, Mr. Paine once more connected the battery, whereupon the machine, in place of starting promptly as before, made a few turns and stopped.

This was, of course, accounted for by the inventor as caused by some derangement of parts; but as a few minutes later I went down stairs I looked at my watch and found that it was five minutes after six o'clock. The building at large contained a steam engine, and power was confessedly used in all other parts except those occupied by Mr. Paine. This remarkable failure to start just about six o'clock, therefore, revealed the actual source of energy. The little battery, without doubt, either operated a belt shifter in a room below, or signaled a confederate similarly located for a like purpose.

Not long after Mr. Paine and his electric engine were unsuccessfully sought for by some of his stockholders, and all that was found was a portion of the iron frame of the machine showing an interior passage for a belt to act on its axle from the room below.

The connection between the arrival of six o'clock and the stoppage of the motor which I had noticed in my visit, and had, of course, referred to its true cause, was thus fully demonstrated.

The risk to which I alluded in connection with such a visit is one of reputation. An ordinary sense of politeness hardly allows one, when visiting a man's workshop on his own invitation, to treat him as if he

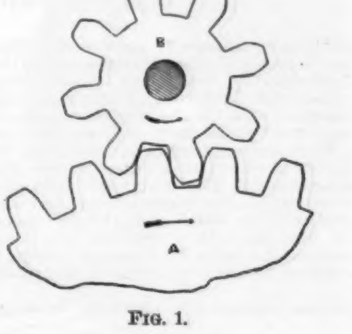


FIG. 1.

were a cheat and his statements as falsehoods, even if we so believe them to be; and thus one, from mere politeness, is almost sure to say something which may be quoted by interested parties as an indorsement, and such statements are very difficult to correct and explain when they have once been put in circulation.

It is, therefore, a very good plan, when one is requested to look into such a matter, to decline unless an agreement is made that every interior detail of the machine shall be exposed to your inspection. In nine cases out of ten this will relieve you of any further solicitation.

On the other hand, to make any agreement not to reveal what you see, as was asked in some cases, as I know, in connection with the Keely motor, is, of course, what no sensible man would do, as it would make it possible to use his name in support of what he might have detected to be a fraud.

It may seem almost needless to say so much on the subject of these gross and conspicuous fallacies; but, while the stock of the Keely Motor Company, in the face of repeated exposures and years of unfulfilled promises, has to-day a value in the market; and when not only such daily papers as are notorious for their lack of truth, honor or decency, but even respectable journals, will publish articles seriously advocating such plans, it is evident that even such fallacies need to be met and exposed by the intelligent engineer.

Besides these fallacies, which involve more or less intentional deception, we encounter others which are the result of perfectly honest, but none the less fatal, mistakes in observation or experiment.

A striking instance of this is furnished by one form of what is known as the aero-steam engine. This was a plan for admitting air into the cylinder of a steam engine at a certain point of the stroke, with a supposed gain in efficiency. A number of experiments were made within my own knowledge with a small engine, or, in fact, model, which seemed to demonstrate conclusively the advantage of this modification.

When the air was admitted, everything else remaining the same, the engine made 20 per cent. more revolutions in a minute against the same resistance.

This was, in fact, thought to be conclusive as to the advantage of the plan. On further investigation, however, it was found that the boiler supplying the steam engine was so inadequate that it could not fill the cylinder for a rapid stroke, and that thus an "exhaust" or back pressure occurred at each stroke when the engine was running fast. The admission of air at a certain point relieved this back pressure and actually increased the duty, but even when so increased it was in

ferior to what it should have been with a well proportioned boiler.

This is, in fact, a type of a large class of fallacies, one or another of which we encounter almost daily.

An inefficient or defective machine or process is taken as a standard, and some attachment or modification is made which greatly improves the result, and it is thence assumed that this attachment or modification would be of equal efficiency with machines or processes in a normal condition.

Thus, for example, a plan for blowing steam into the ash pit of a boiler furnace was, many years ago, extensively advertised, and very remarkable testimonials were shown as to its actual efficiency.

On investigation it, however, turned out that these cases of success occurred where there was a great want of draught in the furnaces, and any means of increasing it would, therefore, have proved beneficial.

The steam blast was, however, a much less efficient way of increasing the draught than any of the well known methods. Such an example teaches the importance of positive measurements in all cases, and the comparison of results with well known and established standards.

Another example of a practical result apparently proving an efficiency which did not exist was brought to my attention some time since, in connection with a pump which developed a pressure much beyond that which would be estimated by calculation of the force applied on the known area of its piston.

It turned out, however, that the piston was so loose that the water passed freely from one side to the other, and thus the pump acted only on the inward stroke, when the piston rod played the part of a plunger whose reduced section, as compared with the piston, accounted for the increased pressure obtained.

This condition of affairs was, of course, betrayed by the small amount of water delivered, as soon as that was observed.

The conditions in this case will be fully illustrated by the accompanying diagram, Fig. 2, in which A B

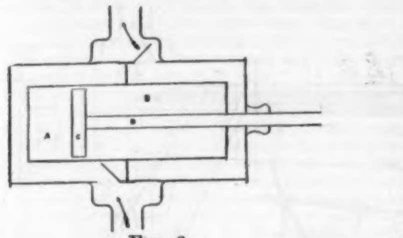


FIG. 2.

indicates a pump cylinder with a piston, C, and piston rod, D. Also inlet and outlet valves and passages, as shown.

If, now, the piston fitted tightly and was moving toward the left, it would force water before it through the upper or outlet valve and draw it in behind through the inlet valve below.

If, however, the piston was so loose that the water could pass freely around it, then, clearly, no water would be drawn in and both inlet valves would close, but the piston rod, as it was thrust in, would displace its own volume of water and force that amount through the outlet. On the reverse stroke no water would be forced out; both outlet valves would be closed, but enough water would enter to fill the space vacated by the withdrawal of the piston rod.

While the volume of water delivered would be thus immensely reduced, its pressure would be proportionally increased, for the force applied to the piston rod, in place of being diffused over the entire face of the piston, would be concentrated on the cross section of the rod.

The lesson this teaches is, when a result is obtained at variance with established principles, don't look for a new law or a new force, but suspect an error of experiment or derangement of the machine.

Such examples as I have just cited teach us also another lesson which may be embodied in a very brief maxim, which is this: "Never make two experiments at once."

That is, when you are investigating a subject and estimating the effect of this or that modification or improvement, never make two changes at once, for then you may easily assign the new result to the wrong one of the two possible causes.

Some remarkable examples of this error were furnished some twenty or thirty years ago in connection with what then excited no small interest among steam users—namely, the "anti-incrustator." This consisted of a group of small magnets sustained by an insulating support in the steam space of a boiler and connected by a copper wire with the shell of the boiler at the other end. This was supposed to prevent the formation of scale in the boiler.

If unexceptionable certificates and the testimony of the most reliable witnesses as to practical results could have proved anything, this was thoroughly demonstrated to be an efficient apparatus. For several years it had a most successful career.

The stock of the company went up like that of some other more recent companies, and, what is more, stayed up, and the anti-incrustators were put into boilers by the thousand. In a few years, however, with wonderful suddenness, the anti-incrustator went out of favor and became a matter of history only.

To explain each instance of its success in operation would be, of course, impossible, but one prominent one will suffice as an example of a large class.

This was brought to my attention at the time by Prof. Coleman Sellers, E.D., of Philadelphia, who was one of the few who at that time declined to accept the evidence presented as sufficient to establish a claim itself intrinsically unscientific and improbable.

A friend of Mr. Sellers had tried some of these incrustators on boilers of his own, and, finding that they ceased to form scale, was convinced, and took a large interest in the company.

In conversation with Mr. Sellers he stated this circumstance, whereupon he was asked: "Did you not make some other change at the time?" "None of any account," he replied. "To be sure, while the boiler was opened to put in the anti-incrustator, we took advantage of the opportunity to disconnect the mud drum, and in place of it, connect the feed with a disused boiler alongside, which we employed as a feed water heater."

Now let me point out that one of the chief scale-producing elements in the Philadelphia water is sulphate of lime, which is less soluble in hot than in cold water. With this fact before you, you will at once see that this gentleman had provided a most admirable "anti-incrustator" in his feed water heater. Here was a large mass of water so heated as to establish only gentle currents, and with a slow circulation, by reason of which the water remained in it a considerable time, and could thus deposit the sulphate of lime, as that became insoluble through the rising temperature. The sulphate of lime also, of course, carried down with it other suspended matters, as all know it will under such conditions.

Here was a clear case of trying two experiments at once, and of assigning the result to the wrong cause.

Next to these, which may be called mechanical fallacies, we come to a more refined and abstruse class, which may be described as chemical fallacies.

Very many who may be quite able to see that no combination of levers, pulleys, wheels, etc., can make a machine operate itself without external supply of energy, or can convert one horse power into two, are not able so readily to see why a pound of coal may not be able to produce more than its regular equivalent of heat.

One of the forms of this fallacy which is most active at the present day is expressed with charming naivete in an article appearing March, 1880, in the Popular Science Monthly, with the title, "Water as Fuel," also in a paper read before the Engineers' Club in Philadelphia, and published in the American Gas Light Journal of February 16, 1880.

The leading fallacy developed in these articles is that involved in the title first quoted, "Water as Fuel."

To anyone understanding the actual conditions this title would be even more absurd than such a one as "Ashes as Fuel," "Rest as a Source of Motion," or the like.

Water is simply the ashes of a perfect combustion, and is no more capable of becoming fuel than the most perfectly burned ashes from a wood or coal fire.

Fully to realize the true relation of this and other like matters, we must take a rather wide view of our chemical surroundings here, as we live on the earth's surface.

We are surrounded by a practically unlimited supply of diluted oxygen in the form of the atmosphere, and all practical combustion must consist in a union of one or another fuel with this oxygen in the air.

While there are hundreds of other chemical combinations capable of producing heat, and which might with great propriety be called combustions, none but those involving the union of some fuel with atmospheric oxygen are practically available, and while, from a purely philosophical standpoint, it is just as proper to call oxygen the fuel and coal the supporter of combustion, yet, in their existing practical relations, it is far more convenient and appropriate, and fully as accurate, to look upon atmospheric oxygen as the universal and freely supplied supporter of combustion, and coal, wood and other materials capable of energetic union with it as combustibles or fuels.

It is these for which we pay, and whose economical consumption is of importance, and the atmospheric oxygen may be safely taken for granted, with only such limitations as to secondary effects of its wasteful use as will, of course, be familiar to all engineers.

Realizing this, it will be evident that the value of any fuel depends primarily upon its capacity of uniting with the oxygen in the air, and that the addition to it of anything which does not possess such a capacity can in no way add to its heat-producing capacity, though, of course, it may render it more convenient of application in certain cases. To illustrate this:

The heat energy in ordinary illuminating gas is by no means greater than that present in the coal from which it was made, but, on the contrary, is vastly less, yet, nevertheless, its convenience of application renders it actually more economical to apply it to a vast number of uses, notwithstanding an immense loss of total heating capacity.

What, then, is the true office of water in its relation to fuel, properly so called? Simply, that of a vehicle which, at a certain sacrifice of total efficiency, nevertheless facilitates the application of the heat energy (derived exclusively from the fuel) under certain circumstances.

In numerous cases solid fuel cannot be brought conveniently in contact with the material to be heated, and then it may be desirable, even at a certain loss of total effect, to turn the solid fuel into a gas for the sake of this increased convenience of application and consequent special efficiency.

In such cases, water may become a useful agency, but you cannot too firmly fix in your minds the fact that its beneficial effects depend solely on this facility of application, and not by any possibility of any contribution by it to the total energy developed in the combustion of the fuel. The oxygen and hydrogen of the water have already developed in their mutual union all the potential energy they possessed in this relation, and, before they can again exhibit any such force, it must be supplied to them from some other source, such, for example, as the combustion of actual fuel, and then what they give out again will be exactly what was thus supplied to them, and no more.

When, therefore, we encounter such statements as that by the use of water with coal the thermal equivalent of the carbon can be practically raised from a theoretical maximum of 14,500 heat units to a practical efficiency of 18,000 heat units, or that six pounds of carbon, whose theoretical maximum is 85,800 heat units, can, by the aid of nine pounds of water, develop 124,000 heat units, let us not mistrust our previous impressions and fall into doubt as to the truth of the great theory of conservation of energy, but look out sharply for a fallacy in the reasoning which has led to such a conclusion.

We should remember, in fact, that while very few things are so improbable that they might not be established by sufficient evidence, yet the amount of evidence must be vastly increased when a seeming result is at variance with established laws, and that we will be well repaid for the closest scrutiny and the utmost deliberation by the avoidance of disastrous errors.

Another common source of error and consequent loss is the neglect in the consideration of a subject of what may sometimes seem trifling practical details, but which often control the question of success or failure.

Thus, for example, it was seen at quite an early date that a hot air engine was theoretically a more economical motor (if questions of practical detail were neglected) than a steam engine. Immense sums of money and a vast amount of the highest inventive genius have been expended on the development of such engines for general use.

The small practical details of excessive bulk in the machinery, consequent friction, the use of very high temperatures, and the like have, however, limited the application of the air engine to a very narrow field.

In like manner, theoretically considered, the magneto-electric machine, deriving its exciting field-of-force from permanent magnets, is manifestly more economical than a dynamo-electric machine whose exciting field-of-force is maintained only by a constant expenditure of active energy. Yet, as a matter of fact, this theoretical economy is more than balanced by the practical impossibility of securing great intensity of magnetic field with permanent magnets, so that the losses caused by the greater friction and electric resistance present in the larger and more complex magneto machines are greater than those involved in the constant generation of a magnetic field by the use of an electric current in the dynamo machines.

Some curious fallacies have been presented to the public within the last few years resulting from a failure to recognize that a horse power did not express an amount of work, but only the rate of doing work. Thus in order that a horse should develop one horse power he must raise 33,000 pounds 1 foot high in each minute of the time he is working, and thus if he works for 10 minutes, he will do the amount of work represented by 330,000 foot pounds, or if he works for 10 hours, his work will be 60 times as much as that, or 19,800,000 foot pounds.

About a year ago a machine was exhibited which may be briefly described as a steam engine employing liquefied ammonia in place of steam. In exhibiting it, promoters caused it to raise 33,000 pounds 1 foot high in 10 minutes, and, reckoning this as a horse power, the machine showed a remarkable economy as compared with an ordinary one horse steam engine. None of the promoters or unprofessional spectators seemed to notice the fallacy or to realize that if this engine and an ordinary one horse steam engine had been working side by side, sawing wood for example, the steam engine would have done as much work or sawed as much wood in each minute as the ammonia engine did in ten minutes, and that thus, at the end of the day, the work or wood pile of the steam engine would be ten times larger than that of the ammonia engine.

In fact, the ammonia engine was not a one horse power machine, but a one-tenth horse power machine.

This incident brings to mind another error which sometimes causes curious mistakes in connection with this same measure of the rate of doing work—i. e., the horse power.

The standard horse power, 33,000 foot pounds per minute, does not mean all that a horse can do, but what he can keep up steadily for eight hours a day.

In starting a heavy load, or in jumping or running, a horse can develop work for a few minutes at a rate many times as great as this. The same is true of a man. Doing steady work hour after hour a man can develop about one-tenth to one-fifth of a horse power, according to circumstances, but under the most favorable conditions an ordinarily strong man can develop work for 15 seconds to a minute at the rate of a horse power. This is on record in "A Treatise on the Construction of Cranes," by J. Glynn, Crosby Lockwood & Co., London, 1880, but is not, I think, generally known.

My attention was first called to it in the following way: I was asked to test a dynamo machine for which the claim was made that it was many times as efficient as the best Brush or Weston dynamos.

I suggested that this was not possible, because the above named machines had efficiencies of between 80 per cent. and 90 per cent. of a theoretical maximum.

The reply to this led to the following questions and answers:

Q. How much power does an ordinary Brush arc light require:

A. About one horse power.

Q. How does a man power compare with a horse power?

A. As about one-fifth to one-tenth to one.

Q. If then one man with the dynamo under discussion can run one Brush arc light, will not that prove the machine to be from 5 to 10 times as efficient as a Brush dynamo?

To this I replied that I would like to see it done.

In due time there came to hand a large flywheel mounted on a frame with a pulley for belting to the dynamo, and a winch to turn it by.

All being arranged it was found that a strong man could in fact keep up an arc light with this apparatus for about 50 seconds.

As soon as this was demonstrated, a dynamometer was attached in place of the dynamo, and this showed that, in the same way, the same man could develop about one horse power for the same time.

It was curious also to observe how completely a man of ordinary strength was exhausted in this or a shorter time when expending energy at this high rate. Experiments narrated in the work above named showed that men practiced in turning a winch could keep up such work for from two to three minutes.

This matter of the true measure of a horse power frequently comes in as an important practical question.

Thus, in considering motors for street cars, it does not at all follow that a two horse steam engine or other motor could practically replace a pair of horses. The two horse engine could exert no more power in

starting the car than at any other time, while the pair of horses could for a few moments work at the rate of 8 or 10 horse power, and so accomplish all that was needed where the engine would fail.

There are certain erroneous impressions as to the true relations of force, energy, and work, originally derived from our personal sensations, which are constantly encountered. Thus, in connection with the early so-called "demonstrations" of Mr. Keely, there was a constant confusion of "pressure" (which is an example of "force") with "work," or its source, "energy," and the public was constantly told that Mr. Keely had discovered a new and vast power, capable of accomplishing vast results in the way of work, because he showed pressures of thousands of pounds on gauges.

If one holds up a weight in the extended hand he is soon as tired as if he had done a considerable amount of work, and it is therefore natural to feel that the mere exercise of force is equivalent to the doing of work.

Work, however, is a compound entity involving not only the exercise of force, but also the accomplishment of motion.

A force of one pound acting by causing motion through a foot will do the work of a foot pound; but a force of a million pounds not moving or causing motion through any distance will do no work.

Work must always be a product of force and distance moved.

A realization of this will save us from the fallicies involved in schemes for the development of "power" from such forces as the expansion of solids or liquids, which, though enormous in their intensities, are limited to insignificant distances in their range of motion. The same principle applies as to many proposed forms of magnetic motors, where the intensity of an attractive force is offset by the shortness of its range.

Another instance of an erroneous impression arising in the same way is the very common one that the reaction of an escaping jet upon the vessel from which it flows depends in some way on the exterior resistance to said jet. If we stood at the stern of a boat, and wished to push the same forward, we could accomplish much more by placing a pole against the shore or some firm obstruction and pushing, than if we had no such resistance to act upon, and, therefore, we feel that if we are trying to propel a boat by driving a jet of water from her stern, a better effect will be secured in proportion as the jet strikes against a more and more unyielding resistance.

In fact, however, the energy expended or work done in so propelling a boat depends solely on the energy or work involved in the ejected jet, and is exactly the same whether the jet is thrown above the water level into the air, below the level into the water, or in some other arrangement into a vacuum. A failure to appreciate this well-established fact involved, within a few years, the useless expenditure of a large sum in attempting to drive a boat by water jets expelled at high velocities, under the impression that the greater resistance to the jet after it had left the nozzle, secured by its high velocity, would produce a beneficial effect upon its "reaction" or power to drive the boat.

IMPROVED ORE WASHING APPARATUS.

WE have on previous occasions described the very interesting processes of treating the zinc ores of the mines of Monteponi, in Sardinia, and the method of magnetic separation of the poorer ores that has been successfully installed by Signor Ferrari, the engineer of the Monteponi Company. We are now able to describe another separating plant designed by the same engineer, which has been working with great success at the Monteponi mines for a considerable time, and which we believe should find a useful application in many other separating works.

This installation is a very simple one, and is illustrated by the engravings. From Fig. 1 it will be seen that one of the most important parts of the installation consists of an endless rubber band 28 in. wide, which is stretched over drums 13 ft. apart, and moving at a speed of 20 ft. per minute over the two drums, one of which is driven by friction gearing. The band is supported by five rollers placed at short distances apart, as may be seen in the illustration. The drums, as well as the rollers, are slightly inclined toward the front, so as to slope the band downward at the delivery edge. The crushed ore, plentifully mixed with water, is fed through a pipe near the upper edge of the band and placed over the driving roller, so that the band for a short distance is covered with the ore-charged water, which is carried on by the traveling belt, at the same time gravitating toward the delivery edge, over which the heaviest particles of ore fall into the receiver beneath, and is washed continuously by a series of water jets playing on the band. This very simple installation has been continuously used in Monteponi for more than two years, chiefly for separating calamine, cerusite, and sulphuret of lead from fine sand. Each jet discharges about 15 gallons of water per minute, and separates about 10 gallons of mixture, and 3 tons of ore can be separated per day of 12 hours. The machine being wholly automatic, but little attendance is required. The arrangement demonstrates that a violent shaking movement is not necessary for separation, for the slower the travel of the sand, and the gentler the jets of water, the better the separation becomes. Experiment has shown that a shaking motion does not improve the work of the apparatus, while it introduces needless complications and increases the cost of working.

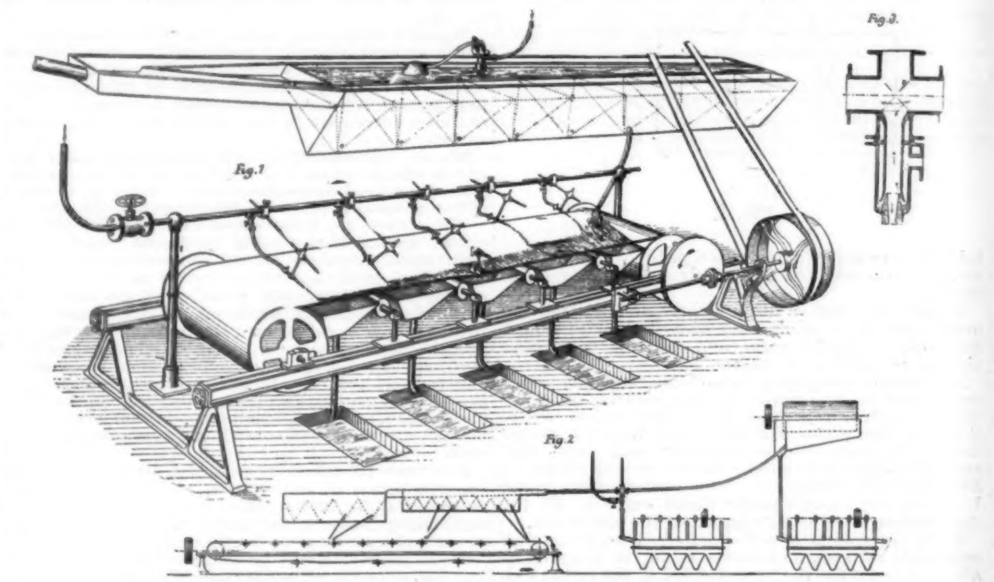
The length of the band may be increased almost indefinitely, when it is desired to use the overflow from other washing tables, such as those at Monteponi already described. The diagram, Fig. 2, indicates such an arrangement in operation; on the right hand side is a sorting screen perforated with holes of from 0·04 in. to 0·06 in.; the mixture delivered by this screen flows with a plentiful water supply through a pipe 4 in. in diameter to the long tank over the separator, to which it is delivered as above described.

In the delivery main a sand separator is introduced which removes the heaviest and largest grains and sends them to the jigging machine described on a previous occasion; this separator is essential to successful working. The large installation, as shown in Fig. 2, can separate 20 tons of ore and sand in 11 hours.

The apparatus allows a great latitude in regard to the quantity of water employed, care being taken, of course, that enough is used to maintain a free discharge. For a 4 in. main it is necessary that from 40 to 50 gallons should flow per minute; the main leaves the hopper in which the screen works, with a fall of 30°. The sand separator which is introduced in the main is but little known, although it has been used for over 15 years at Monteponi. Fig. 3 shows its construction, and its operation is as follows: The mixture, passing through the pipe, enters the horizontal part of the junction at high pressure, and meeting a vertical opening, the heaviest particles naturally tend to fall, but the tube is incased in a larger one, in the side of which there is a valve admitting water also under pressure; this descends and then rises into the inner tube to a certain height as indicated by the arrows, checking the sand from escaping, but permitting the heaviest particles to fall and flow to the jiggers.

In this apparatus the density of the grains of ore is far more important than their weight; for example, in the combination shown in Fig. 2 of a set of jiggers and the band separator, two-thirds of the separated ore goes to the jiggers and only one-third to the bands; this division is wholly effected by the sand separator.

In an installation containing four band separators and four jiggers, the first delivers from one-half to two-thirds of the lead ore, although the average material passed through each machine is equal. The fourth apparatus produces scarcely any lead ore, and in the third the grains are extremely small, while the rock particles average 0·04 in. in size; this great difference in size greatly facilitates the work of the jigger. While the densest grains have a downward tendency, the accelerated speed of the mixture in the sand separator carries with it all specifically lighter grains, and the denser ones fall. This is proved by the fact that the separators only work properly when they are far enough apart; that is to say, the mixture requires a certain length of pipe and of time for the grains to settle again and prepare for another separation.—Engineering.



ORE WASHING APPARATUS AT THE MONTEPONI ZINC MINES.

[FROM THE NINETEENTH CENTURY.]

RECENT SCIENCE.

DIPHTHERIA.

THERE is no doubt that diphtheria has lately attained an alarming frequency in Europe. To say nothing of Russia, where the last epidemics had swept away nearly all children in many villages, we find that in Prussia no less than one-sixth to one-fourth part of all children dying in the age of from one to five years succumb to diphtheria;[1] and the same proportion must have lately prevailed in western Europe as well. One fully understands, therefore, the keen interest which is taken at this moment by the general public in the experiments of the French doctors Roux and Yersin, who try to cure diphtheria by means of the blood serum of animals previously vaccinated against that disease. However, the scientific importance of these experiments is even greater than their immediate utilitarian value. Serum-therapy has a direct bearing upon nearly all infectious diseases; and it touches upon some of the most burning questions relative to the fundamental problems of life; while the manner in which the researches have been conducted is such that there is hardly in the whole domain of modern science another branch which could better illustrate the best methods of scientific investigation applied to a most complicated subject, or better contribute to the general promotion of scientific methods of thought.

That diphtheria, like tetanus (or lockjaw), with which it has much in common, or like anthrax, cholera, malaria, and so on, is due to an infection of the body by special bacteria is by this time an established fact.

Without an infection by either the bacteria discovered by Loffler, or the poisons which they secrete, there is no diphtheria. But it is also known that the powers of different animal species, and even of different individuals, to resist infection vary a great deal, and that they can be weakened or increased by vaccination, so as even to confer full immunity. This being true of nearly all infections, the attention of bacteriologists is chiefly directed now toward finding out what is the cause of the poison-resisting powers of the organism, how they are acquired, and how to strengthen them.

Two years ago E. Metchnikoff's ingenious theory of immunity was analyzed in this review[2]. According to this theory, the organism which has been successful in its struggle against infection owes its recovery to a victory which has been won by its amœba-like white cells, or leucocytes, over the infecting microbes. As soon as poisonous bacteria are introduced into the animal body, the free white cells—i. e., the white corpuscles of the blood and the lymph, and the so-called wandering cells—probably attracted by the secretions of the bacteria, gather in immense numbers at the spot of infection. There they wage a war to the intruders.

If they are healthy and numerous, and if the bacteria do not multiply too rapidly, so as to overpower the leucocytes in numbers, the latter absorb the microbes, enveloping them with their protoplasm and rendering them inoffensive. In some cases the leucocytes actually digest the microbes—that is, dissolve them and absorb them—thus fully deserving the name of microbe-eaters or phagocytes; in other cases they simply keep them enveloped in their protoplasm, and without killing them, prevent them from casting spores and multiplying; or else, as it would appear from some recent researches, they carry them away to the liver, the lungs, and partly the spleen, where the intruders gradually decay. Wonderful as these statements are, they are facts and not theories. The leucocytes really come together in their millions at the infected spots, hastening thereto from all parts of the body;[3] and hundreds of microscopical preparations, showing to the eye how the leucocytes envelop the microbes with their protoplasm, have been made in the laboratories; many of them have been figured in the works upon the subject.[4] Consequently, the reality of the absorption of the microbes by the leucocytes (the "phagocytosis") is now generally recognized, and the importance only of this struggle between two sets of cells, as compared with other possible means of protection against infection, is now under discussion.

Other agencies, besides the leucocytes, most probably intervene, and during the last few years a great deal of attention has been given to these agencies. It has become evident that the action of bacteria is very complicated. In some cases the poisoning bacteria must be associated with various species of other microorganisms, inoffensive in themselves, but probably required to prepare some favorable conditions for the multiplication and the deadly action of the former. Without the aid of their associates the poisoning bacteria may have no effect, as has been proved several times with cholera and typhoid fever, and is well known for tetanus bacilli. Again, the bacteria may simply destroy some cells of the body—this is the way of the malaria parasites, which destroy the red corpuscles of our blood[5]—or they may attack the tissues of some special organs; or they will deprive the cells of the body of the plastic elements, or gases, necessary for their life, and so to say, starve or suffocate them. But their effect may also be more indirect; they develop, also, what we call, for want of a better knowledge of the subject, some poisons—some living, ferment-like "toxines"—which affect the fluids of the body, and especially its blood, and, through it, the whole organism. Since Koch discovered his "tuberculin," these poisonous products of the bacteria have been studied a great deal; and, although we are very far from a somewhat precise knowledge of their nature, we know, nevertheless, that most "toxines," although deprived by filtration of all bacteria and bacteria spores, exert upon the animal body the same deadly effects as the bacteria themselves—they provoke the same disease.[6] And, finally, there is in the animal body another class

[1] Professor Behring, Die Geschichte der Diphtherie, mit besonderer Berucksichtigung der Immunitatslehre, Leipzig, 1893.

[2] "Recent Science," Nineteenth Century, August, 1892.

[3] Their disappearance from the blood immediately after infection has lately been confirmed by several explorers.

[4] We are glad to state that Metchnikoff's Lecons sur la pathologie comparee de l'inflammation has by this time been translated into English by T. A. Starling and E. H. Starling. Notwithstanding its rather technical title, the reading of this little and suggestive book can safely be recommended to non-specialists.

[5] For all concerning the malaria microbes see the excellent work of Dr. Julius Mannaberg, Die Malaria-Parasiten, auf Grund fremder und eigener Erfahrung dargestellt, Vienna, 1893.

[6] Besides the researches of Koch and his school into the properties of tuberculin, a wide number of works ought to be named under this head. Such are the studies undertaken by Roux and Widal (at the Institut Pasteur), and Wooldridge in 1888, into the poisons secreted by the diphtheria and the tetanus bacteria; the investigations of Brieger and Frankel into the poisonous albumines ("toxalbumines"); and those of E. H. Hankin, Kanthack and Dr. Sydney Martin into the "toxines" and the protective "anti-toxines."

of ferment-like albumoses, also very imperfectly known, which also develop out of the activity of bacteria, and which seem to meet in the body the effects of the above poisons. The British Medical Journal has proposed for them the very good name of "defensive proteids."[7] These "anti-toxines," whatever their nature may be, undoubtedly develop in the blood, and especially in the serum of animals which have caught certain infectious diseases and have recovered from them; and, consequently, another—that is, a fourth—branch of research has grown up, the explorers of which want to know whether blood altogether, and especially its serum, as well as other liquids secreted by the body, and especially milk, do not possess immunity-conferring, or even curative, properties. This is the branch of bacteriology which interests us most at the present moment, especially as regards the applications of blood serum to the cure of diphtheria.[8]

For many years past Doctors Richet, Hericourt and Klein, amid general indifference, have advocated the use of the watery parts of blood—the serum—as a means of protecting animals against infection, and insisted upon its curative properties. However, their opinions passed unnoticed. All that preparatory work concerning the bacterial poisons and the anti-toxines, which has just been mentioned, had to be done before the importance of the serum could be properly understood and demonstrated. It was, therefore, only at the end of 1890, when the German doctor Behring and the Japanese bacteriologist Kitasato published the results of their elaborated researches that the whole matter was put on a firm scientific basis.[9] Modern serumtheraphy, as acknowledged over and over again by Roux and all other explorers, dates from these memoirs.

The development of Behring's ideas is extremely interesting, and it admirably illustrates the present aspects of bacteriological research. Rats, as is known, are resistent to several infective diseases, including anthrax. While mice, rabbits, guinea pigs, sheep and horned cattle rapidly succumb to an infection of anthrax bacteria; rats do not catch the disease. This was known years ago, and it had also been remarked, in laboratory experiments, that while anthrax bacteria thrive in the serum of the last named animals, they rapidly degenerate in the serum of rats.[10] It was natural, therefore, to suppose that the same takes place in the living organisms, and that the resistance of rats and the susceptibility of mice, rabbits and so on, are due to the different bacteria-killing properties possessed by the serum in these different species. But experiment directed this way refused to support the hypothesis. Animals whose blood showed no bactericide properties in the laboratory were found to be immune against certain diseases; while, on the other hand, animals whose blood destroyed the bacteria in a glass bottle were not always immune. Some experiments were in favor of the hypothesis, but others were dead against it, and there remained nothing but to submit to the verdict, however undesired it was.[11]

These negative results were arrived at at a time when Roux and Yersin, who studied diphtheria, and Kitasato, who worked on tetanus, had succeeded in obtaining out of the secretions of the respective bacteria such powerful poisons that it became possible to provoke both diseases by injecting the poisons alone, after all bacteria and their spores had been carefully eliminated from the injected matter. Illness and death evidently resulted in such cases, not from some action of bacteria upon the cells of the animal, but from a general poisoning, whatever that poisoning might be. Accordingly, Behring and Kitasato and several other bacteriologists at once began to experiment upon such substances as might paralyze the bacterial poisons, even though they might be unable to kill the bacteria themselves. Various chemicals were tried, and for some time great hopes were entertained as to the chemical treatment. But again the results were utterly disappointing. It appeared that the effects of the chemicals are mostly quite local, and that to be of any use they must be applied immediately after the infection takes place. Their practical value is, therefore, extremely limited.[12]

Nevertheless an important point was won by such researches. Behring and Kitasato found, to their astonishment, that if the spread of tetanus in an animal had been stopped by any sort of chemical treatment, the blood of that animal, although it was unable to kill the bacteria of tetanus, paralyzed the poisons evolved by the bacteria. The animal was rendered immune against infection; and when the two doctors attempted to cure tetanus by means of the serum of such blood, they at once obtained results which went far beyond their expectations. To quote but one instance: several mice were dying from inoculated tetanus, when an injection of the serum of an immune rabbit was tried upon one of them. Improvement became apparent at once, and it was followed by recovery, while the other mice died in a few hours. The cure for tetanus was thus found, and this was what Behring and Kitasato announced in their epoch-making memoir in December, 1890.

But now that the final aim seemed to have been reached, new difficulties arose. The first successes were not always confirmed by subsequent experiments, and, in proportion as the field of research was widened, failures became more and more frequent. Then it was much more difficult to obtain a serum for diphtheria cases than it was for tetanus. Moreover, large quantities of serum were required for the serum cure, and they could be obtained only by conferring immunity against diphtheria on larger animals very susceptible to diphtheria—a feat which was found by no means easy to accomplish. Happily enough, the two explorers made no secret of their discoveries, so that new and easier methods of vaccination were sought for and discovered, especially by Roux and Yersin.

It would not be possible to relate here the details of these memorable researches.[13] Sufficient to say that gradually the following method was elaborated, and that it proved successful for big animals as well. Instead of introducing a deadly virus, and then trying to cure it by chemicals, an attenuated diphtheria (or tetanus) poison was used for vaccination—all bacteria and their spores having been removed by filtration from the vaccinating liquid, and the morbid properties of the poison itself having been reduced by the addition of certain chemicals.[14] This attenuated poison was injected into a quite sound sheep (or horse) in such limited quantities as to obtain but a very feeble reaction of fever; and the injections were repeated until the animal was accustomed, so to say, to the poison, and no more fever was provoked by subsequent injections. Then stronger doses, up to three and six cubic inches of the attenuated poison, were resorted to; and when they also had no marked effect, an injection of the most virulent diphtheria poison, such as would kill outright an untrained sheep, was attempted. If it did not provoke diphtheria, the sheep or horse was considered immune, and the serum of its blood could be used to cure diphtheria in other animals.[15] This method was gradually perfected, and it was discovered by Roux that the serum need not be drawn each time afresh. It may be desiccated, and kept for a long time in such a state without losing its properties.

The curative effects of such serum are really wonderful. A guinea pig usually dies from inoculated diphtheria in thirty-six to forty-eight hours. But an injection of a very small quantity of serum ($\frac{1}{5000}$ part of the weight of the patient), if it be made a quarter of an hour after the inoculation of the poison, prevents the appearance of the disease. If the treatment begins at a later period, say eight hours after the inoculation, ten times more serum is required. Even twenty-four hours after the infection takes place the animal can be saved by an injection of serum attaining $\frac{1}{100}$ part of the animal's weight. Its blood is renewed; it requires new forces, and it destroys the poisons of diphtheria which were rapidly bringing the disease to a fatal end.[16] With tetanus, injections of serum are effective even in a more advanced stage.

Moreover, as shown by Kitasato and his colleagues,[17] the same method is applicable to Asiatic cholera, erysipelas, hog cholera and anthrax. Immunity at least, or, more correctly, a resistance to poisoning, is easily obtained for these diseases as well; and in cholera immunity is conferred so rapidly—in twenty-four hours—that the treatment has very much the characters of a real cure. A wide field is thus opened for most promising discoveries.

In how far the serum treatment may be relied upon for man is still a question to be solved by experiment, and upon which Roux, Behring, Kitasato, Ehrlich, and all the above named explorers, as well as Tizzoni and Cattani in Italy, are now busy at work. The brilliant successes announced from time to time in the daily papers must certainly be received with caution. But in view of the undoubted, though not always infallible, successes obtained with animals, and the fair proportion of successful treatment of men, we can be hopeful. In some cases the cures have been most remarkable. Moreover, we learn from statistics which reach us as we write these lines, that Roux, at Paris, has obtained seventy-four per cent. of cures in three hundred ascertained cases of diphtheria, already treated by the serum; and that Professor Ehrlich, at Berlin, has had eighty-five per cent. of recoveries in the one hundred and sixty-three cases treated by the new method. There were only two failures out of the seventy-two cases in which serum was injected during the first two days of the disease.[18] Such results are more than reassuring.

The theoretical value of these investigations is self-evident. Important points have been won, and new and broader vistas have been opened. Metchnikoff's theory of immunity has certainly not been overthrown by the discoveries which have been recently made. On the contrary, the part played by the phagocytes in the struggle against infection is fully recognized even by such promoters of the serum theory as Buchner and Roux. It has been proved, moreover, that an injection of an antitoxic serum provokes a marked increase in the numbers of leucocytes in blood,[19] and it appears probable[20] that the leucocytes of a vaccinated animal differ from those of other individuals of the same species in being capable of more rapidly attaining their stage of full development, when they are more active in absorbing microbes. But it also becomes more and more apparent that the phagocyte theory will require some further extension. Perhaps, if the views developed by Hericourt upon infectious disease altogether[21] prevail in science, it will be found that phagocytosis and the struggle between the bacterial poisons and the anti-toxines of the serum correspond to the two different phases which, according to Hericourt, are marked in each infectious disease. But we must first learn what the toxines and the anti-toxines are. Up till now we can only say that they are living matter, and that they must be considered as ferment-like substances; but we do not know what is the reason of their action upon each other, and bacteriologists have not yet succeeded in separating them from each other in the laboratory. Perhaps the modern researches into the structure of the cell, which prove that each cell is a world in itself,[22] will throw some light upon this difficult subject, and some day we may learn that the toxines and the anti-toxines belong to the category of those component self-reproducing elements of the cell which have been named pangenes by De Vries.

EARTHQUAKES.

The destructive earthquakes which have lately visited Italy, Greece, Turkey and Japan have again brought to the front the long since debated question as to the probable origin of those grand trepidations of the soil. Great divergence of opinion undoubtedly prevails still among geologists; but some accord begins also to be established upon the chief points at issue, so that the main features of an earthquake theory can already be delineated.

A really scientific study of earthquakes is of relatively recent origin. It may be said that it dates from the great catastrophe at Naples in 1857, when H. R. Mallet worked out, in his classical report,[23] the methods of investigation of earthquakes, and when Palmieri, establishing his seismometric observatory on the slopes of Vesuvius, attracted general attention to the necessity of special instruments for measuring the movements of the soil. Each earthquake of importance has been carefully investigated since, and the spot or the line, from which the disturbance originated, as well as the depth at which it lay below the surface, have been carefully determined in each case. In many places the tremors of the soil are now carefully measured and registered by means of special instruments; and although it was found very difficult to devise an instrument which would accurately record the movements of the soil, the chief difficulties have gradually been overcome, and the records of our seismometers and seismographs, properly interpreted, give already a good idea of the waves which spread in the soil. As to the delicacy of the modern tools used for detecting the slightest tremors, it is sufficient to say that by means of the new seismometrograph established at the Collegio Romano it was possible to observe at Rome not only the earthquakes which took place in Greece, India and Turkestan, but also to see on March 22 last, three distinct waves coming from three distinct shocks in Japan. They had traveled over an enormous distance—nearly one earth quadrant—at a speed of about 2,750 yards in the second, and yet were visible in the tracings by the instrument. But the new bifilar pendulum devised this year by Mr. Horace Darwin is even still more promising; it can record and measure a tilt of the earth's surface of less than $\frac{1}{100}$ part of a second[24]—that is, a change of level which would occur if a line one mile long were lifted by one-thousandth part of an inch at one of its extremities. And, finally, direct experiment is now called in to the aid of the young science, and artificial earthquakes having been provoked both by explosions of mines and by the fall of heavy masses of iron, their effects upon delicate instruments have been carefully studied. The tools of the seismologist thus attain a high degree of perfection.

In studying the distribution of earthquakes upon the surface of the globe the annals of all countries have been ransacked, and monumental catalogues have been compiled by H. R. Mallet, Alexis Perrey, and Fuchs, and, quite lately, by Orloff and Mushketoff for Russia and the adjoining lands of Asia. Special centers have also grown up for a detailed study of earthquakes, in South Italy, Greece, and Japan[25]—especially in Japan, the land of earthquakes and earthquake studies—where invaluable data are collected by sending out all over the country scores of thousands of post cards, which are returned every week to the Seismological Institute, with notices of the shocks experienced at each spot.

There is also no lack of investigations relative to the distribution of earthquakes in time, their supposed periodicity, and their possible connection with the seasons of the year, the relative positions of sun and moon, the atmospheric pressure, the electric earth currents, and so on; and if the expectations of Falb and Perrey, who have tried to predict earthquakes, have not been fulfilled, we may still hope that warnings similar to those which are issued for coal mine explosions will some day be possible. One fact of importance appears, at any rate, with certainty from these investigations, namely, that earthquakes are decidedly more frequent during the winter months than during the summer, and that their frequency stands in some not yet fully determined connection with atmospheric pressure.[26] Of course this does not

[7] See E. H. Hankin's "Report on the Conflict between the Organism and the Microbe" in British Medical Journal, July 12, 1890; also his review of Behring and Kitasato's work in Nature, December 11, 1890, xliii. 121. Indications of the corresponding literature are given in both papers.

[8] Its literature is immense. Indications relative to it will be found in the quoted works and reviews. Buchner's reports to the Hygienic Congresses at London (1891) and Buda-Pesth (this year) are excellent reviews of the whole question, the more so as Buchner is one of the chief workers in this branch.

[9] Behring and Kitasato, "Ueber das Zustandekommen der Diphtherie-Immunitat und der Tetanus-Immunitat bei Thieren," in Deutsche medizinische Wochenschrift, 1890, 49, p. 1113. Analyzed in Nature by Mr. Hankin, December 11, 1890, xliii. 121.

[10] I follow in this sketch Behring's own description of the evolution of his ideas, as given in his introduction to his and Kitasato's memoirs, "Die Blutserumtherapie bei Diphtherie und Tetanus," in Koch und Flugge's Zeitschrift fur Hygiene und Infectionskrankheiten, 1892, xii. 1-10.

[11] A long series of such experiments was made in Bouchard's laboratory; so also by Behring and Nissen.

[12] The limited effect of chemicals will be better illustrated by the following: Dr. Calmette, the chief of the Bacteriological Institute of Saigon, having once received from a locality infested by cobra snakes a barrel containing fourteen living specimens of the snake, utilized this opportunity for studying the means of combating the deadly poison. He experimented with all sorts of chemicals. It appeared, however, that although permanganate of potassium at once destroys the cobra poison in a glass tube, and precipitates it, it has but little effect in the animal body unless it is introduced into the wound immediately after or simultaneously with the inoculation of the poison. Otherwise the latter rapidly spreads through the body, and can be paralyzed no more, either by the permanganate or by ammonia. Chloride of gold is but a little more efficacious. If the spreading of the poison is slackened by ligatures, and injections of chloride of gold are made all round the wound, and on the way of the poison from the wound to the central parts of the body, there are some chances of recovery; but the whole must be done very quickly in order to prevent the spreading of the poison ("Observations experimentales du Venin de Naja tripudians ou Cobra capel," in Annales de l'Institut Pasteur, 1892, vi. 160).

[13] The reading of the chief original papers, namely, by Behring and Kitasato, in the Zeitschrift fur Hygiene (1892, xii., 1-81), and by E. Roux and L. Vaillard in the Annales de l'Institut Pasteur (February, 1893, vii., 64-140), can be recommended to non-specialists as well as others.

[14] Roux prefers iodine, while the German explorers prefer iodine trichloride, or a chloride of gold and sodium. Many other chemicals, including peroxide of hydrogen, were experimented with before these three were chosen.

[15] Behring's Die Geschichte der Diphtherie, pp. 160-165.

[16] Behring and Wernicke, "Ueber Immunisirung und Heilung von Versuchsthieren bei der Diphtherie," in Zeitschrift fur Hygiene, 1892, xii., 10-44; also Behring's Geschichte der Diphtherie, p. 184.

[17] S. Kitasato, L. Brieger and A. Wassermann, "Ueber Immanitat und Giftfestigung," in Zeitschrift fur Hygiene, 1892, xii., 137-182. For immunity through milk, P. Ehrlich, in same volume, p. 183, where copious bibliographical indications are given. Kitasato attenuates the bacterial poisons by cultivating the bacteria in preparations obtained from the thymus gland. His researches thus join hands with the most remarkable therapeutic results obtained by Brown-Sequard and D'Arsonval, and they tread upon the ground which has been so well reviewed lately by Professor Schafer in his presidential address before the British Association at Oxford.

[18] M. A. Ruffer, in Nature, November 1, 1894, li., 18.

[19] Roux and Vaillard recognize the fact in the above quoted memoir, p. 91.

[20] Mademoiselle C. Everard, J. Denmoor and J. Massart, "Sur les Modifications des Leucocytes," in Annales de l'Institut Pasteur, 1893, vii., 187-194. See also Metchnikoff's fifth memoir on immunity in the same volume.

[21] Revue Scientifique, November 15, 1884, xxxiv., 619.

[22] See "Recent Science," in this Review for December, 1892, p. 1013.

[23] Great Neapolitan Earthquake of 1857, 2 vols., London, 1862.

[24] C. Davison, in Nature, July 12, 1894, l., 249.

[25] The Transactions of the Seismological Society of Japan, named now The Seismological Journal of Japan (edited by J. Milne), are full of the best information relative to earthquakes altogether.

[26] Sjogren, "Om jordkorpans sammanpressning under atmosfertrycket," in Ofversigt af Vetenskaps Akademiens Forhandlingar, 1888, ii. 131, has lately promoted the idea that the compression of the strata by high pressure favors the outbursts of subterranean gases. R. Langenbeck holds a similar opinion (in Gerland's Geographische Abhandlungen aus Elsass-Lothringen, 1892, Heft l.) Gunther (Beitrage zur Geophysik, Bd. ii. 70) has lately paid

mean that cold seasons, or a high atmospheric pressure, or even the supposed tidal action of the sun and the moon upon the elastic earth's crust, may be considered as causes of earthquakes. They must be taken only as additional impulses aiding to break an already unstable equilibrium which originates, according to the now prevailing views, from the dislocations of the strata themselves, chiefly due to aqueous causes.

The study of earthquakes thus stands now on a firm scientific basis. As to their causes, current opinions are undergoing just now a deep modification. The theory of earthquake origin which has till lately prevailed in science, and which had for it the authority of Humboldt and Leopold Buch, is well known. Earthquakes and volcanic eruptions were considered as effects of a common cause, the never-ceasing reaction of the hot and molten interior of the earth upon its thin solid crust. When water, percolating the rocks or running down their fissures, reaches the depths at which the temperature is so high that rocks and metals are maintained in a liquid state, steam is evolved under a formidable pressure, and, together with the gases originated from the molten mass itself, it accumulates in the subterranean cavities. Rows of volcanoes rise along gigantic trends which are opened in the earth's crust, and they act as so many safety valves for the escape of the gases and steam; but if one of these valves be obstructed for some reason, the pressure of the gases grows, until they open a passage through the solid crust, bringing the rocks into a formidable commotion.

The theory was grand. It brought into causal connection a wide range of volcanic and seismic phenomena; it inspired research. Who does not remember the beautiful lines devoted by Humboldt in his Cosmos to this subject? However, even at the time these lines were written the theory was beginning to inspire serious doubts. Was not the cause too grand in comparison with its results? Would not the molten nucleus break the thin crust to atoms if it stood in such free intercourse with the atmosphere? Local hearths of chemical activity would do as well to explain volcanic action, and local disturbances in the superficial strata would perfectly well explain the greater number of earthquakes. In fact, when we know that the mere fall of the steam hammer in Krupp's gun factory shakes the houses and their windows for several miles around;[27] that the explosion of a mine loaded with gunpowder or dynamite is felt many miles off; and that the mere trampling of a holiday crowd is reported to the astronomers of Greenwich by the behavior of their levels, we feel disinclined to appeal to the molten nucleus, and we look for causes nearer at hand.

Gradually, the very existence of the molten nucleus of our planet became more and more problematic. Already the mathematical investigations of Fourier and Poisson had shown that, owing to our very imperfect knowledge of the physical aspects of the question, we are reduced to mere conjectures as regards the state of the inner parts of our globe.[28] Later on, the admirable investigations of Sir William Thomson, G. H. Darwin, Mellard Reade, Osmond Fisher, R. S. Woodward, and others rendered the existence of a molten nucleus surrounded by a thin solid crust less and less probable. And the geologist had to conclude that, so long as physics would not supply more reliable data for mathematical investigation, he had better leave the question as to the physical state of the inner parts of the earth unsolved, and study the dynamic processes which are going on in the superficial layers of the planet. The more so as the subsidence of strata undermined by water, the disturbances of equilibrium which result from the transport of immense masses of matter by the rivers, and the accumulation of deposits in their deltas; the side pressures so well illustrated by the folding of the strata; the chemical processes which must go on in the rocks at relatively small depths; and the forces originating in the crystallization of rocks, are agencies largely sufficient to explain both the activity of volcanoes and the most severe subterranean shocks.

Research was accordingly directed toward a study of the local causes which might have given origin to each separate earthquake. There is, of course, a number of earthquakes directly due to volcanic causes; but these, as already indicated by Humboldt, are always limited in their areas and are the minority. As to the greater number, their causes must be sought for in local disturbances of the rocky strata. Everywhere there are softer strata which are disintegrated by water between the rocky layers above and beneath them. One day or the other they must yield; and when they do yield, their subsidence, or the gliding of the upper strata upon a softened intermediate layer, must result in an earthquake. And when the geologist looks for a local cause of an earthquake, he finds that some such disturbance has really taken place. Such was the case in the great Naples catastrophe of 1857; such was again the case in the Irkutsk earthquake of 1861–62, when all information pointed to the delta of the Selenga, where a large area subsided, and 140 square miles of land were covered with the waters of Lake Baikal to a maximum depth of seven feet.[29] The great earthquake of Middle Japan, in the year 1891, had again the same character. It was found that a rent was opened in the superficial strata for a length of more than forty miles, and that on one side of the rent the strata had subsided by as much as twenty feet in the places of maximum subsidence. And all indications agreed in pointing to this rent as the line from which the earthquake waves had proceeded, so as to leave no doubt as to the subsidence being the cause, and not the consequence, of the earthquake.[30] Moreover, in this case, as in all others, after the sudden subsidence had provoked several severe shocks, thousands of smaller shocks, proceeding from the same locality, continued to be noticed for a year or so, until a succession of smaller subsidences had brought the displaced mass to a rest. The great earthquakes which affected in April last the northeastern region of continental Greece had the same character. A great fissure, thirty-five miles long, was opened, and on one side of the fissure the Plain of Atalante was lowered and slightly shifted toward the northwest;[31] and similar, although submarine, changes of level were observed during the earthquakes which visited Zante and the Gulf of Corinth in 1873, 1886–90, and April, 1893.[32]

For almost every great earthquake which has taken place during the last thirty years the cause was found in local dislocations and subsidences. But while our knowledge of the local causes was thus progressing, the part which belongs to earthquakes in the general life of the planet was lost sight of. Some broader generalizations, the necessity of which Humboldt insisted upon, were required, and they were given in the epoch-making work of Suess, The Face of the Earth.[33] The "local dislocation" theory is fully indorsed by Suess; but these dislocations themselves are treated as but separate instances of the activity of those "tectonic" or building forces which continually remodel the earth's surface, create the abysses of the oceans and the depressions of the continents, and lift up the highest mountains. Starting from the idea that the cooling of the globe results in a steady decrease of its diameter, and consequently in a continuous shrinking and shriveling of its outer strata, Suess endeavored to show how this process would work in producing the leading features of the earth's surface. He described how large areas have been and are still sinking bodily, producing the great faults which intersect our rocky formations; how semicircular depressions arise on the borders of the highlands; and how the lateral pressures developed during the shrinking of the outer layers result in lateral pressures which fold the strata and lift them into mountain chains. The earthquakes under this broad conception of "geotectonics" appear as simple trepidations of the soil by which the shrinking of the crust and mountain building processes are necessarily accompanied.

Kant had already remarked that most earthquakes take place on the seaboard. Modern research fully confirms this view, and goes a step further. It maintains that by far the greatest number of earthquakes —perhaps ninety per cent., as Professor Milne says —originate beneath the sea, where the rocks, under the superincumbent hydrostatic pressure, are continuously saturated with moisture, and can the easier be displaced. In fact, in nearly every earthquake in Japan, the center of disturbance of which could be determined, it was found to lie a short distance off the eastern coast of Nippon. The same is true of the earthquakes which have lately visited Greece, as illustrated by the breakages of submarine cables, which undoubtedly indicate that considerable changes of level have taken place at the bottom of the sea.[34]

And the same is true, again, of the Constantinople earthquake of July last, which had its center of disturbance in the Sea of Marmora, at a short distance from San Stefano.[35] In short, it may be taken as a fact that a great number of earthquakes, to say nothing of the sea tremors, which also are numerous,[36] originate at the sea bottom, near the sea coast.

However, not all sea coasts are equally liable to be visited by earthquakes. The flat lands of Subarctic Asia, which gradually merge into the shallow Arctic Ocean, are seldom disturbed. A steep slope of the sea bottom itself, or of an elevated land toward a deep sea, is a necessary condition for both earthquakes and sustained volcanic action. The eastern coasts of the Japanese archipelago, which face the till lately unfathomed abysses of the Northern Pacific and the abrupt slope of the Chilean coast of South America, are well-known instances in point.

The deep depressions of the bottom of the East Mediterranean, where a depth of over 2,000 fathoms is found within twenty miles from the island of Rhodes; the western coast of Southern Greece, facing the 2,170 fathoms deep abyss of the Ionian Sea which separates it from Sicilia; the Neapolitan coast, separated by but a hundred miles from the 2,000 fathoms depth of the Tyrrhenian Sea; and so on—all these facts enable geologists to formulate another law, namely, that steep slopes, either from the land to the sea or of the sea bottom itself, are another condition for frequent earthquakes.

But even in this form the law would not be complete, as it would not include the disturbed regions of the continents, and it is most remarkable that, when worded accordingly, it applies to continents also. In the very heart of Asia there are two regions where earthquakes are especially frequent, and both of them lie along the steep northwestern border of the Great Plateau of Central Asia, where it abruptly falls from the heights of the Tian Shan to Lake Issyk-kul, and from the heights of the Khamar-daban (about 8,500 feet high) to the 750 fathoms deep Lake Baikal. A third depression of the same kind—also a hearth of earthquakes—is situated on the northeast border of the plateau of Persia and Armenia, where the 15,900 feet high Savelan rises over the deepest parts of the Caspian Sea, marked by the 500 fathoms line; while farther west we have the depression of Vienna, lodged between the northeastern Alps and the northwestern Carpathians, which has been so well described by Suess as another center of earthquakes. Moreover, the three first named depressions, like the so much disturbed Gulf of Tokyo, or the Bay of Arauco in South America, are semicircular depressions, carved out in the edge of the highlands; and this further confirms the above mentioned views of Suess.

However, a further step seems to be required in the development of the hypothesis. The most severe earthquakes undoubtedly take place on the borders of high plateaus, whether these plateaus slope toward the ocean or whether they rise over flat lowlands surrounding them. But all plateaus are fringed by border ridges, which gently rise over their elevated surfaces all along their edges, as well as on the edges of the separate terraces which are so frequent in the plateaus of Asia and America. This feature is too general to be merely accidental, although it has hitherto remained quite unexplained. It is therefore possible to suppose that the subsidences which take place, chiefly along the borders of the plateaus, must have a double effect—that of lowering the levels of the surrounding lowlands or plains (or of the adjoining sea bottom) and of lifting up at the same time the tops of the inclined strata; this process, repeated for ages, resulting in the formation of the border ridges, which are a necessary accompaniment to all plateaus of the Old and the New World. And as these border ridges mostly are, or have been in recent geological times, the seats of intense volcanic activity, we see that earthquakes and mountain building are thus brought again into connection. But this hypothesis, which I venture to add as a further extension of Suess's views, lands us on a new domain—the origin of mountains—which may be better treated separately on some future occasion.

FLYING MACHINES.

Great hopes have been revived again among aeronauts by the experimental flights of Dr. Lilienthal in Germany and the partial successes obtained with their flying machines by Messrs. Maxim and Phillips in this country, and Mr. Hargrave in Australia. For more than a half century inventors in aeronautics have been treated as foolish dreamers, and no later than two years ago an American professor who wanted to address his students on the subject of mechanical aviation felt it necessary to seriously beg his audience not to interpret his choice of the subject as a token of declining mental faculties. But, happily enough, these dark times are over, and aeronautics is becoming a regular department of scientific research.

The general revival of science which we witnessed in the early sixties has given new life to this branch of research, and we have now an excellent scientific literature devoted to the subject, several aeronautic societies (one in Great Britain) which are doing excellent work, and several reviews in the pages of which aeronautics is discussed in a scientific spirit.[37]

The services rendered by balloons during the last siege of Paris are well known, and since that time steady progress has been achieved both in the mode of construction of balloons and the art of aerial navigation.[38]

By taking advantage of the different directions of wind at different heights, which begin to be better known, and may be ascertained by means of pilot balloons, the navigator to some extent chooses his own direction, and with the new anchors and guide ropes, landing, which is the most dangerous part of ballooning, has been so much simplified that balloon trips are now as safe as any other kind of sport. For meteorology the balloon is a precious aid, and a good deal has been learned from the aeronauts about temperature and electricity in cloudland, while unmanned balloons, provided with self-registering instruments, as has been found by M. Hermite, can bring us down the most precious information from those highest strata of the atmosphere in which Mr. Glaisher nearly lost his life.

The idea of adding a propeller to a balloon, and thus enabling it to navigate close to, or even against, the wind, is certainly not new—Girard had already realized it in 1852—but the practical application of his idea had to contend with many technical difficulties. The deformation of the balloon, which takes place as soon as it begins to progress against the wind instead of being carried with it, had to be prevented. A light but powerful motor had to be devised under the limitation of employing no fire for it, and a number of minor obstacles had to be overcome. Accordingly, although propelled balloons are now the pets of the ministries of war in the big states, and money is freely spent upon them, the advance is still very slow. The greatest speed ever attained by the French officers Renard and Krebs with their cigar-shaped balloon, propelled by a storage battery motor, was only fourteen miles to the hour. True, that even with this modest speed the balloon could be navigated in a feeble breeze, so as to return to its starting point, after having described a triangular route; but in order to brave the wind a speed of fifty miles is required, and all that the French officers expect from their new balloon is a speed of twenty-five miles, which will enable it only to take tacks in a moderately fresh breeze.[39] Moreover, there being but little hope of discovering a gas the density of which would be still smaller than that of hydrogen, the dimensions of a propelled balloon must remain very great, in proportion to the useful weight it can carry. The new French balloon (as remarked by Mr. Chanute) will be of the size of a river steamer, and yet it will hardly carry more than four passengers; and a further increase of size would be of little avail, in proportion to the cost of the ship. Consequently, scientific research and invention are now directed more and more toward the flying machine, which, being much heavier than an equal volume of air, will find in its very density and inertia the means of contending against the currents of air.

We have under our very eyes a most perfect flying machine—the bird—and we have only to study, from a physical point of view, the laws of its flight, in order to find out the laws which must guide us in our schemes. This is what science has tried to do ever since the time of Leonardo da Vinci. But, owing to a want of interest in such researches in the general public, the scientist had hardly completed his work ere it was forgotten. The wonderful observations and physical reasonings and experiments of Leonardo da Vinci had to be rediscovered a few years ago.[40] Even the

a good deal of attention to the subject, and came to approve of Sjogren's idea (in Naturwissenschaftliche Rundschau, ix. 20). For all concerning earthquakes Professor J. Milne's excellent little volume of the "International Science Series," and S. Gunther's Lehrbuch der Geophysik (2 vols. Stuttgart, 1884), will be found trustworthy guides.

27 The fact had been indicated by Mohr in his Geschichte der Erde (Bonn, 1875), which was so much scoffed at at the time of its appearance for its pronounced Neptunist ideas.

28 For a capital review of the mathematical theories of the earth, see R. S. Woodward's presidential address in American Journal of Science, 1889, xxxviii. 337 seq.

29 Orloff and Mushketoff's Catalogue, St. Petersburg, 1893.

30 B. Koto, "On the Cause of the Great Earthquake in Middle Japan in the year 1891," in Journal of the College of Science, Tokyo, 1893.

31 S. A. Papavasiliore, "On the Earthquake of Locrio of April, 1894," in Comptes Rendus, 1894, cxix. 112, 380; analyzed in Nature, l. 607.

32 W. G. Forster, in Mediterranean Naturalist, April, 1893; analyzed in Nature, April 27, 1893, xlvii. 620.

33 Ed. Suess, Das Antlitz der Erde, 2 vols. Prague, 1885. This work of first importance has not yet been translated into English.

34 W. G. Forster, "Earthquake Origin," in Transactions of the Seismological Society of Japan, Yokohama, 1890, xv. 74, 77.

35 Charles Davison, in Nature, September 6, 1894, l. 450.

36 See E. Rudolph's monograph of the same in Gerland's Beitrage zur Geophysik, Stuttgart, 1887, Bd. i. 133.

37 L'Aeronaute is published at Paris since 1869. The Zeitschrift fur Luftschiffahrt und Physik der Atmosphare is a sister review to the Zeitschrift fur Meteorologie, and is published by the German and Austrian Aeronautic Societies. A new review, the Aeronaut, has been started this year in America. And so on.

38 For the technical part of the subject and the succession of inventions, see the new book of Mr. Chanute, Progress in Flying Machines, New York, 1894. Also his address before the Congress of Aeronautics at Chicago.

39 It is 215 feet long and 40 feet in diameter. The motor, 45 horse power, will weigh, with fuel for ten hours, 3,400 pounds.

40 Amans, "La Physiologie du Vol d'apres Leonard de Vinci," in Revue Scientifique, mai 26, 1892, xlix. 687.

admirable work of Borelli, who wrote on the flight of birds in 1680, and the very valuable researches of Silberschlag, published in 1783,[41] were little known; nay, even the work of Cayley, which dates from 1796, had fallen into oblivion. Modern science had thus to begin anew, and it began by dismissing, first, certain prejudices which had taken hold of most minds.

One of these prejudices was to believe that the warm gases contained in the cavities of the bird's body and its quills render it lighter than an equal volume of air. Everyone can, however, calculate how insignificant the effect of that warm air must be;[42] and everyone knows that a bird which has been wounded on the wing falls at once to the ground. This prejudice could easily be discarded; but another, as to the immense force which the bird is supposed to develop during its flight, is much more difficult to get rid of. No amount of evidence, borrowed from what everyone can verify by dissecting the muscles of a bird, or by observing the ease with which it flies, could overthrow that very common error, supported by the most fallacious calculations of a French mathematician made in the early part of this century.[43] It took Professor S. Langley in America nearly four years of careful experiments to show how erroneous were both those calculations and the data upon which they were based.[44] Now we can at last take it as granted that, although the energy spent by birds in sustaining themselves in the air varies a great deal according to their shapes and manners of flight, it is less than one one-hundredth to two one-hundredths of one horse power for each 2 lb. of body weight. And, as art has already succeeded in producing small prime motors whose weight does not exceed 10 lb. per horse power, one sees at once that the problem to be solved by the flying machine offers no mechanical impossibility, provided we learn to utilize the energy of our motor as well as the birds utilize their forces.

The next step to be made is, accordingly, to learn from the birds how best to utilize the force of a motor, and therefore to study the mechanical details of birds' flight. Science has done this well, and we have already most excellent guides for this part of the problem in the works of the Duke of Argyll, Mr. Pettigrew, Mouillard, and the fundamental work of Marey (Le Vol des Oiseaux), in which last all such problems have been treated with the aid of instantaneous photographs, taken at intervals of small fractions of a second, not to speak of many others, each of which contains some valuable information.[45] It would be impossible to describe here in a few words, and without the aid of drawings, the admirable mechanism by which the bird drives the air with its wings (rigid at the front edge and flexible at the back), compresses it, and has only to progress forward in order to sustain itself in the air in spite of the action of gravitation. This must be read in the above named works and seen on Marey's photographs. But what must be said is, that a continuous rotatory movement being more advantageous in a machine than a mechanism which would be an imitation of the flapping of the wings, the best form to be given to a screw propeller which has to act in the air was indicated by such investigations. It was found already by Leonardo da Vinci, and worked out by Cayley in 1796. It has been lately studied experimentally by several physicists, meteorologists, and inventors—all experiments proving the considerable lifting powers of a screw propeller in the air. And we have now a direct proof of these powers in Maxim's machine. His propeller, which rotates in a medium having such a small density as air has, communicates nevertheless to the heavy machine, with its motor, aeroplane, and a dozen passengers, a horizontal speed of nearly forty miles in the hour. Half the problem is thus solved, because, as shall presently be shown, a great horizontal speed is the first condition of aviation.

We all know, indeed, that most birds, before they can rise in the air, must acquire a certain horizontal speed. Many good fliers can be kept prisoners in an open small yard surrounded by walls twenty feet high, or even on a small open pond surrounded by low but grassy shores, upon which the bird cannot take the necessary run.[46] But once a bird has acquired this speed—and it mostly acquires it by running against the wind—it flies with a wonderful ease; its spread wings and its speed sustain it. Once in motion, the swallow and many other birds will fly any amount of time, hardly using at all their wings for flapping.

These observations, supported by a number of theoretical investigations by Wenham, Froude, Langley, and others, into the resistance of the air, naturally suggested to inventors the idea of the "aeroplane"—that is, of a thin rigid surface, inclined by very few degrees (not more than five) to the horizon, and moving horizontally, edge forward. The particles of air which strike the surface under a certain angle spend part of their energies in lifting it, and this lifting power, as foreseen by experimenters and lately supported theoretically by Lord Kelvin, is very much greater than was supposed.[47] A great number of experiments have already been made to measure the lifting powers of different surfaces placed under different angles of inclination and moving at different speeds, especially by Professor Langley; but if there remain some doubts as to the correctness of the result, Maxim's machine should dispel them. Those who have traveled on its platform unanimously maintain that it hardly touches the ground when it is launched at a speed of nearly forty miles, and that, were it not prevented from rising, it would do so, as soon as its speed or the aggregate surface of its aeroplanes were slightly increased.

To be lifted in the air, and to move in it in a horizontal direction, is, however, one part only of the problem. The other is to maintain equilibrium, which is continually modified by the continually changing pressure of air upon the different parts of the aeroplane or the superposed smaller aeroplanes. The bird feels the changes of pressure on its wings, and gently alters their position, in the same way as the bicyclist feels the slight alterations of equilibrium and changes accordingly the relative positions of his two wheels. But a flying machine must accomplish this automatically; and before this is achieved, some better acquaintance with the minute details of the art of flying will necessarily be required. This is what gives an especial interest to the flights which Otto Lilienthal has performed in Germany.[48] He adjusts to his body a pair of moderate sized concave wings, and after having taken a run down a gently sloping hill, always against the wind, he is soon lifted in the air. Floating at a certain height over the ground, against the wind, he glides down a gently sloping line without ever attempting to flap with the wings, and he lands some 100 to 300 yards (occasionally, 500 yards) from the spot where he left the ground. Of course, this is not flight properly speaking, but, as foreseen by Lord Rayleigh in 1883, it is through such experiments that we may learn the technics of flying and steering. Through them we learn also a good deal about the lifting force of the wind. Thus, during one of his experiments, Lilienthal was caught by a gust of stronger wind, and instead of being thrown backward by it, or being overturned (this last was prevented by a timely maneuver of the feet), he was lifted to a higher level than the spot where he left the ground. He simply received an object lesson in soaring.[49] It is known, indeed, that when a fresh breeze is blo wing, many big birds, after having reached a level of from 200 to 300 feet by means of strokes of their wings, remain almost motionless in the strong breeze, and by simply changing the inclination of their wings and the direction of their gliding they graduall y rise to the level of 2,000 and 3,000 feet, as they describe their great spirals. Rising in the air, without spending any muscular effort, certainly sounds like a paradox; but the best naturalists, including Audubon and Darwin, are unanimous in testifying that in such flight the birds do not flap their wings; they even do not move the feathers of their wings; and it now appears certain, after a long discussion has run through the papers on the subject and exhaustive experiments have been made, that no such movement is needed in reality. The bird, gliding against the wind, is lifted by it and rises to a higher level, in the same way as Lilienthal was thrown upward against his own will; and it takes advantage of the thus gained height for gliding down a slightly inclined line and for acquiring velocity, which permits it again, after it has turned against the wind, to win in height. But still these maneuvers did not well explain how the bird could gradually rise to a higher level, and some uncertainty continued to prevail about the matter.

The key to the puzzle (fore seen by Lord Rayleigh as early as 1883,[50] and indicated by Mouillard) was finally given this year by Professor Langley, again on the basis of physical experiments, in which the American physicist is known to excel. The explanation is in the "waves and gushes" of which every wind consists. Wind, we now learn, is not what it is usually considered to be. It is not "a mass of air in motion," but consists of small masses moving with such irregularities of speed as we never suspected before. By means of very light paper anem ometers, the rotations of which were measured every second, instead of every minute, Professor Langley ascertained that the velocity of wind is continually changing. It varies every second, and while the average velocity may be twenty-three miles, it will, in the course of one minute, be altered several times, from twenty-three miles to thirty-three miles, back to twenty-three, then to thirty-six, then fall to zero, and so on. So that a heavy bird which glides with a certain velocity through the air can constantly utilize the gushes of the wind to be lifted, without ever using its wings for flapping. It has, as Professor Langley shows by direct experiments upon floating surfaces, merely to change the inclination of its wings in order to win in height, and then to spend part of the potential energy in acquiring velocity,[51] all this with the judgment which it derives from its experience of the medium it lives in. The differential energy of the gushes supplies the necessary energy for lifting the bird. These considerations explain why birds succeed with so little or no effort in rising to great heights, or in covering immense distances. They do what the boatman does when he takes advantage of a gust of wind to progress under sail. They may be said to take tacks, but in a vertical direction.

The above sketch can only convey a very faint idea of the rich body of data upon which scientific investigation bases its conclusions as to the full possibility of aerial navigation by means of a machine which is heavier than air. All the elements of the problem are being settled one after the other by experiments and calculations, and the points in which the aid of the mathematician is especially required are indicated. The data are there, and what is wanted is the creative inspiration to utilize these data. And in this direction, the machine of Mr. Maxim, the very successful models of Mr. Hargrave, worked by small steam engines,[52] and the flying experiments of Lilienthal, are important steps already made. The solution thus seems to lie now within a measurable distance from our own times—unless a wind of reaction, such as has already blown twice in the past, comes to throw again into oblivion all that has been done up to this date.

P. KROPOTKIN.

[41] Schriften der Berliner Gesellschaft der Naturfreunde, Bd. ii., 1781-1784.

[42] Its effect can counteract but one fifty-thousandth part of the weight of the bird (Marey, Le Vol des Oiseaux, p. 287).

[43] Navier (Memoires de l'Institut, ii., 1829) maintained that, in order to sustain itself in the air, a swallow spends a force of one-seventeenth of a horse power. Langley found that force fifty times smaller. Even the calculations of Babinet, a supporter of aviation, were quite erroneous, as shown by Marey (Le Vol des Oiseaux, p. 328).

[44] S. P. Langley, in Smithsonian Contributions to Knowledge, 1891, p. 801; and American Journal of Science, November, 1891. Also Lord Rayleigh's discussion of the same in Nature, December 3, 1891 (xlv., 108), where indications to the works of Mr. Wenham and Mr. W. Froude will be found.

[45] The chapter devoted by the Duke of Argyll, in his Reign of Law (first edition, 1866), to the flight of birds is a masterly work, based upon his and his father's observations, and imbued with a thorough knowledge of nature. The same qualities will be found in the more exhaustive works of Mr. Pettigrew (Animal Locomotion . . . with a Dissertation on Aeronautics, London, 1873) and Mouillard (L'Empire de l'air: Essai d'Ornithologie appliquee a l'Aviation, Paris, 1881); while the large work of Marey (Physiologie de la Locomotion Le Vol des Oiseaux, Paris, 1890, which must not be confounded with his earlier work) is an exhaustive treatise, based upon observations made with the aid of chronophotography. Some of the earlier works are already named. See also Lilienthal's Der Vogelflug als Grundlage der Fliegekunst, Berlin, 1889; T. d'Esterno, Du Vol des Oiseaux, Paris, 1864; Goupil, La locomotion aerienne, Charleville, 1884, etc., each of which contains valuable observations.

[46] Mouillard (L'empire de l'air) has made the experiment with Procellaria.

[47] Nature, August 30, 1894. Of course, there is a certain relation between the area of the surface and the weight it has to support. In large birds, a surface of wings 10½ square feet easily supports a weight of 18 lb. A concave surface, as shown by Lilienthal, supports a greater weight than a plane surface of equal area.

[48] See his work on the subject, his later papers in the Zeitschrift fur Luftschiffahrt. Dr. A. Dubois Reymond's account to the Berlin Academy (December 15, 1893), and the accounts given in Nature (vol. l.) and the aeronautic papers.

[49] The diagram of this case is given in the Zeitschrift fur Luftschiffahrt, 1893, ii. 259.

[50] He remarked in Nature (xxvii. 535), at the end of a long discussion which had run through the paper, that wind is not uniform, and he inquired "whether anything can be made of the difference of horizontal velocities which we know to exist at different levels." Leonardo da Vinci was also very near to this solution. He also explained the rising of the bird by the "waves and gushes" in the air.

[51] S. P. Langley, "The Inner Work of Wind," in American Journal of Science, 1894, third series, xlvii. 41.

[52] Journal and Proceedings of the Royal Society of New South Wales, 1892, xxvi. 170, and 1893, xxvii. 75.

THE RISE OF ORGANIC CHEMISTRY.

By VAUGHAN CORNISH, M.Sc., F.C.S.

ORGANIC chemistry, the study of the hydrocarbons and their derivatives, is a science of the present century. Some of the technical processes connected with the preparation of organic substances are, however, of very ancient origin—brewing for instance, and the art of soap making. It is the scientific aspect of the subject with which we are concerned in the present article, and which occupies the greater part of Prof. Smithells' new and enlarged edition of Schorlemmer's "Rise and Development of Organic Chemistry."

Lavoisier showed that the decomposition of sugar by fermentation proceeds according to the conditions of the law of conservation of mass, the carbonic acid and alcohol produced being equal in weight to the sugar from which they are formed. Early in the present century the Swedish chemist, Berzelius, showed that the composition of organic substances conforms to the laws of constant proportions and of multiple proportions, which Dalton and others had shown to be characteristic of mineral compounds. The way was now paved for the recognition of the study of organic materials as a part of the domain of chemistry, conforming to the same laws as those which govern the chemical properties of mineral substances.

Research in the organic branch of chemistry was immensely facilitated by Liebig's work in perfecting the principal process of organic analysis, the well-known "combustion" which is still the pons asinorum of the student's laboratory course. From Liebig's time the progress of organic chemistry has been marvelously rapid. The compounds of carbon are, for the most part, so "reactive" that the labor of the investigator is quickly rewarded by the production of some novel substance—often useful or curious—the discovery of which leads in its turn to the production of other bodies related to, but differing from it. The binding element in the majority of these is carbon. The carbon atoms seem to have an almost unlimited capacity for catching hold of and hanging on to one another, and at the same time they retain their hold upon one or more atoms of other elements with which they have been associated. Thus, in the laboratory of the plant or animal body, and in the laboratory of the chemist, are built up compounds of almost infinite complexity, though containing for the most part but few of the chemical elements. Carbon is present in all, hydrogen in almost all, and oxygen in a majority of cases. Nitrogen occurs frequently, and the other elements in smaller quantity and comparatively seldom. The known hydrocarbons—i. e., compounds containing only hydrogen and carbon—number four hundred, while few of the elements except carbon combine in more than two or three proportions with hydrogen.

The total number of carbon compounds is said greatly to exceed that of all the other known chemical substances. Among the organic bodies which have been produced in the laboratory are many useful drugs and invaluable anæsthetics; dyes, of which many are brilliant and some are beautiful; and powerful explosives, the discovery of which has probably proved beneficial to manufacturers of war material. But in the limits of this article we must not diverge from science to technology.

The facility with which chemists can transmute one carbon compound into another has led to great developments in our knowledge of the mechanism of chemical reactions, and of the chemical structure of substances. Chemical formulæ, from expressing merely the quantitative composition of compounds, were soon used to express the methods of formation and decomposition of organic substances. As knowledge advanced it was seen that the formulæ could be made to indicate the way in which the atoms were united one to another. It appeared from the study of organic chemistry that the attraction or union of an atom is not so much with all the rest of the molecule as with some neighboring atom with which it is closely united or related. The graphic formulæ, with which modern chemical books are full, express, symbolically, the order or arrangement in which the atoms of the compound molecule are bound or linked together. To such perfection has the symbolical expression of the constitution of organic substances been brought, that the manipulation of these symbols often furnishes a valuable guide in the prosecution of new researches. No mode of expressing graphically on paper the composition of a molecule can, however, be expected to be quite satisfactory, if it fails to take account of the fact that the atoms of a molecule are not all distributed, and do not all move, in one plane. The ordinary graphic formula of the text book has the same faults as, say, the Bayeux tapestry, or a Chinese battle picture—it takes no account of perspective. The more recent use of glyptic symbols (which look like outlined figures of crystal form), or of actual models, is an important extension of this domain of scientific symbolism.

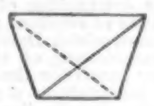
We must explain shortly how these developments have come about. The study of carbon compounds led to the discovery of isomeric bodies which differ in their properties, although their analytical composition is identical. These differences must, it seems, be explained on the supposition of a different grouping of the chemical atoms, and the phenomena of isomerism are to be classed along with those of allotropy, which are exhibited by several elementary substances, notably by carbon itself (vide Knowledge, 1892, "Carbon"). In the case of carbon compounds,

it was found possible in many cases to express these differences by the graphic formulæ referred to above. Thus, there are two substances of very different properties, the percentage composition of which is expressed by the formula $C_2H_4Cl_2$—the symbols C, H and Cl standing for weights of carbon, hydrogen and chlorine, proportional to the weights of the atoms of these bodies. It was found that in one of the two substances whose composition is expressed as above, both chlorine atoms were bound up to the same carbon atom, whereas in the other the reactions showed that each carbon atom was in intimate connection with only one atom of chlorine. These facts are symbolized as follows:

$$\begin{array}{c} H \\ | \\ H-C-H \\ | \\ Cl-C-Cl \\ | \\ H \end{array} \quad \text{and} \quad \begin{array}{c} H \\ | \\ H-C-Cl \\ | \\ H-C-Cl \\ | \\ H \end{array}$$

But these graphic symbols are insufficient to explain some cases of isomerism. For such cases it is useful, instead of using the symbol $-\overset{|}{\underset{|}{C}}-$, to represent the carbon atom by a tetrahedron.

This symbol expresses the essential fact that the carbon atom has a fourfold power of union with other atoms, and we symbolically express the union by attachment to the corners of the figure. It is generally



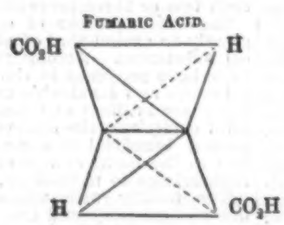
sufficient for the purpose in view if one or two carbon atoms are thus fully represented, the ordinary symbol being employed to show the functions of the other carbon atoms. The two substances, fumaric acid and maleic acid, have the molecular composition $C_4H_4O_4$, and the study of their reactions shows that each has two groups CO_2H, in which the hydrogen is bound to carbon only through the connecting link of the oxygen atom, whereas the remaining two hydrogen atoms are united directly to carbon. Two graphic representations may be made, which in a condensed form appear thus:

$$CO_2H.CH.CH.\ CO_2H$$

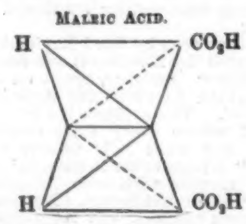
$$\text{and} \quad CH_2.C \begin{cases} CO_2H \\ CO_2H \end{cases}$$

The latter symbol would indicate that two CO_2H groups are united to one carbon atom. The reactions of the substance so represented are, however, altogether against this supposition, and the graphic representation, therefore, fails. If, however, we represent the functions of two of the carbon atoms more fully by symbolizing these atoms as tetrahedra, we can represent very well the observed differences in the two acids by taking account of the arrangement in the solid instead of regarding the apparent arrangement on the flat. In the symbols given below the dotted lines of the tetrahedra indicate those edges which would be invisible if we were dealing with a wooden model, or with any opaque crystal of the same form.

FUMARIC ACID.



MALEIC ACID.



A class of bodies which it is difficult to represent by any symbol are those known as tautomeric, in which one or more atoms appear to be in a state of alternating allegiance toward their more powerful neighbors. The hydrogen atom, which is the lightest and probably the fastest mover in the dance of atomic vibration, seems in some cases to have certain peculiar privileges of motion within the molecule, so that at successive moments it may be joined up to different atoms.

In the work of synthesizing or building up compounds which occur in nature, the organic chemists soon outstripped their "inorganic" brethren. Lately, however, the French representatives of inorganic chemistry have again recovered the lead, and the diamond has been made, while starch and the albuminoids are still beyond the creative powers of the chemist. The early feats of organic synthesis were hailed as a triumph over the old belief in a mysterious vital force. All substances produced in the life processes of animals and plants were supposed to owe their existence to the mysterious agencies of life, and to be inimitable by the chemic art. The synthesis of a host of such substances in the laboratory has shown that the mysterious powers of vitality were prematurely invoked, and that failure was presupposed when no true trial had been made. The case is somewhat analogous to the mistaken appeal to almost infinite periods of time as the condition of formation of the native crystals of ruby and diamond. In spite of all their past achievements, scientific men are ready enough, like other mortals, to cry out that their go-cart cannot get any further without the aid of some Herculean agency beyond their reach. As a matter of fact, however, the achievements of organic synthesis have only pushed the vital force theory a small distance further back, for none of the reproduced alkaloids, sugars, dyes, etc., are organized bodies, or show any sign or symptom of the germ of living power. Recent researches upon the molecular weights of organic substances (chiefly by Raoult's method, which is based upon the lowering of the freezing point of solvents) appear to show that the simplest among the substances which are intimately associated with vital processes are of vastly higher molecular weight, and presumably vastly more complicated than any of the substances that have yet been synthesized. The great differences in the size of molecules is perhaps indicated by the phenomena of dialysis, so much used in physiological work for the separation of substances.

Crystalloids, sugar for instance, will in solution pass through the pores of an animal membrane, such as parchment†, whereas colloid substances will not. It seems likely that in such substances, perhaps through the action of atoms, such as those of carbon, which have a power of multiplex combination, molecules or groups of atoms may "combine to net-like or sponge-like masses. . . . We may perhaps further suppose that through the constant change of position of polyvalent atoms, these mass molecules will show a constant change in the connected individuals, so that the whole . . . is in a sort of living state.*

"The idea thus brought forward may perhaps be expressed by saying that if ever chemists should succeed in obtaining albuminous bodies artificially, it will be in the state of living protoplasm." ("Rise and Development of Organic Chemistry," p. 261.) Now that an independent cell life in the organism has been recognized, the distance seems but small which separates the organic chemist from the point where he may be expected to make his first serious attempt to ascertain if living matter can be produced otherwise than by the agency of living matter itself. Not every scientific man would be able to approach this world-old question without a preconceived opinion as to the ultimate answer which Nature has in store. Whatever be the answer which Nature has in store for us, it will be a duty to science to work at the problem until it is either solved in the affirmative, or, like the transmutation of metals, found by experience to be beyond our power. Hitherto chemistry has not been in a position to attack the problem. The synthesis of organic compounds must be carried still further before science will have a bridge long enough to span the wide and formidable gap which divides our knowledge of the inanimate from that of the living world.—Knowledge.

* "In crystals and in dead bodies generally, matter is in static equilibrium. . . . In living organisms the equilibrium is dynamic."—Nature, November, 1894.

CHROMIUM FLUORIDE IN WOOL DYEING.

A FEW years ago there was introduced to the notice of wool dyers a new mordanting material in the shape of the fluoride of chromium, known commercially as fluoride of chrome, in the form of a green powder fairly readily soluble in water. This product has met with considerable favor from wool dyers, although the advantages it possesses over bichromate of potash should have caused it to become more used than what it has been. Probably the prejudice which all old dyers unfortunately have against anything new has been against its adoption. Of course, its being rather more expensive than the older bichromate of potash may have been against it; but as the difference of cost cannot be large, its advantages over bichrome ought to counterbalance this.

Fluoride can be employed in the dyeing of wool with certain dyestuffs where bichrome would be perfectly unsuitable. Such is the case with diamine fast red F, Titan yellow Y, Emin red, benzo fast red, and a few others. These coloring matters are first dyed on wool from the usual acid or neutral baths, then the dyed goods are boiled for half an hour longer, in a fresh bath, with a small amount of flouride of chrome (2 to 3 per cent.), when shades are obtained of great fastness to light, air and milling. In the case of diamine fast red F, the fastness of the reds so obtained is fully equal to those dyed with the alizarine reds, while in that of Titan yellow the fastness is fully equal, if not superior, to that of alizarine yellows. With such dyes bichrome is not available; owing to its oxidizing properties, it acts upon and more or less destroys the color matter on the fiber.

In dyeing with chrome on wool the main object is to bring about the deposition of green hydroxide of chrome on the wool, except in certain cases—in dyeing logwood blacks, for instance, where some chromic acid should be fixed on the wool. When bichrome is used alone this deposition does not take place to any great extent, and it becomes necessary to add sulphuric acid, oxalic acid, or tartar to the bath. In the first case, not only is hydroxide of chrome deposited, but chromic acid also, and this exerts a deleterious effect on some dyestuffs—anthracene blue for instance. In the last two cases this effect does not occur, and hydroxide alone is deposited. In any case, however, the final effect is only obtained after a prolonged boiling. At first chromic acid is deposited, and this gradually changes into hydroxide, the change being indicated by a change of color in the wool, from yellow to green. The treatment should always be prolonged until this takes place. Usually there are employed from 3 to 4 per cent. of tartar or oxalic acid; very deep shades may take 5 per cent. of bichrome. The whole of the bichrome is not used, about half remaining in the mordanting bath.

In the case of dyeing with fluoride of chrome, the hydroxide is deposited immediately on the wool. Hence in using this substance the treatment need not be so prolonged. Thereby the wool is not liable to become felted or tangled, as it may be under a longer treatment. Less fluoride (from two to three per cent.) is required, with half the quantity of oxalic acid. One hour's boiling is quite sufficient for the darkest shades, while if pale tints only are being dyed, half an hour is sufficient—a feature of no little value as enabling pale tints to be dyed with alizarines of a more uniform shade than is possible with bichrome-mordanted wool; for in the latter case the wool contains much chromic acid, which, on the wool being allowed to lie about, as may happen, is changed by the action of light and air, in those places to which they may have access, into hydroxide, and the dyeing, therefore, is liable to be uneven. Wool is much softer when mordanted with fluoride of chrome than when mordanted with bichrome, owing to the absence of any oxidizing influence on the wool.

Mordanting with fluoride proceeds better in old than in the new baths, and so the mordanting baths may be retained for constant use, adding about three-fourths of the original quantities of the fluoride and oxalic acid for each successive lot of wool.—Textile Mercury.

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